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EFFECT OF MID SEASON DROUGHT STRESS ON ROOT TRAITS, ROOT SHOOT RATIO AND PROLINE CONTENT IN GROUNDNUT GENOTYPES WITH CONTRASTING DROUGHT TOLERANCE

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ABSTRACT

Maximum yield losses under drought situation coincide with pegging, pod formation and pod development stages in groundnut. Among the eleven genotypes analyzed under midseason drought, TCGS 1157 and MLTG 4 were found to be most drought tolerant and Narayani and Kadiri 6 were found to be highly sensitive to moisture stress. Prominent leaf folding was observed in drought tolerant genotypes such as TCGS 1157 and MLTG 4 to reduce the evapotranspiration losses within 15 days after moisture stress imposition. In contrast, drought sensitive genotypes like Kadiri 6 and Narayani did not exhibit leaf folding phenomenon resulted in withering and drooping of leaves at 65 DAS. TCGS 1157 and MLTG 4 displayed better ability to expand their roots than Narayani and Kadiri 6 under moisture stress situation. The extent of increase in root shoot ratio is more in drought tolerant genotypes (79-103%) when compared to susceptible genotypes (31-53%). The increase in proline content was more in Kadiri 6 and Narayani than in TCGS 1157 and MLTG 4 at 20 days and 30 days after stress imposition. Sensitive genotypes were subjected to severe stress at early stages as they did not show any water saving mechanisms like leaf folding which was prominent in drought tolerant genotypes. This leads to increased evapotranspiration rates in Kadiri 6 and Narayani and thereby synthesizes more proline to maintain osmotic potential. Therefore, the increased levels of proline under drought stress can be better considered as a stress indicator in plants.

KEYWORDS: Genetic variability, PCV, GCV, heritability, genetic advance, pod yield, groundnut.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the most important food and oilseed crop cultivated globally in 25.44 m ha with a production of 45.22 mt (FAOSTAT : Anonymous, 2014). About one-third of the groundnut produced globally is consumed as table purpose and two-thirds are crushed for oil. In India, groundnut productivity is 937 kg/ha and is below world average (1037 kg/ha) (Anonymous, 2014). This low productivity is mainly due to production constraints such as the cultivation of the crop on marginal lands under rainfed conditions, occurrence of dry spells due to vagaries of monsoon and low input-use.

Drought triggers a wide variety of plant responses, ranging from cellular metabolism to changes in growth rates and crop yields. Mid-season drought coincides with critical growth stages such as pegging and pod filling stages (50-100 Days After Sowing (DAS)) causes more yield loss than other phenophases. Groundnut genotypes exhibit a variety of drought avoidance strategies such as leaf folding, modulation of root and shoot growth and increased production of osmoregulants like proline. The root system is critical to plant adaptation under drought conditions. Root traits, particularly root length and biomass are expected to play an important role in avoidance of drought in receding soil moisture conditions by improving water availability to the plant through more efficient extraction of available soil moisture. In groundnut, water stress stimulates the growth of roots into deeper layers and vegetative growth is completely ceased. In addition, prolonged water stress resulted in smaller leaves, reduced internodal length and no effect on number of nodes. Proline accumulation is a common metabolic response of higher plants to water deficits where it contributes substantially to the cytoplasmic osmotic adjustment.

To bridge the prevailing yield gap, genotypes with good root mining ability and drought tolerance need to be developed which can significantly contribute towards mitigation of drought effects and can provide a long-term solution to rainfed farmers.

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MATERIALS AND METHODS

Plant material

Groundnut genotypes namely TCGS-1398, Kadiri-9, TCGS-1157, TCGS-1073, TCGS-1173, MLTG-4, Kadiri-6, Narayani, TPT-1, ICGV-07132, ICGV-07070 were screened for tolerance to mid season drought in pot culture experiments in rainout shelters. Drought stress is imposed by withholding water from 50DAS to 80DAS coincides with peg formation and pod development under field condition for evaluating the influence of water stress on morphological (leaf folding, root length and root shoot ratio) and biochemical parameter like proline content.

Leaf folding

The diurnal variation in young leaflets with increased duration of moisture stress was recorded visually at mid season drought stress period (50-80 DAS).

Root length and root shoot ratio

The root length and root shoot ratio were recorded in well watered and respective drought stress imposed genotypes at the time of final harvest using standard methods.

Leaf proline content

Proline content of the leaf was estimated as per the procedure of Bates *et al*. (1973) with slight modifications. 500 mg of fresh leaf sample was finely grounded with liquid nitrogen and macerated with 10ml of 3% (w/v) sulphosalicylic acid. Samples were centrifuged at 8,000 rpm for 15 minutes at 4°C and 2ml of supernatant solution was aliquated into a new test tube. To this, 2 ml each of ninhydrin and glacial acetic acid were added and incubated at 75°C in hot water bath for 1 hour and then cooled to room temperature under running tap water. 4 ml of toluene was added to this contents and stirred uniformly for 30 seconds. Proline collected in upper pink layer was estimated by OD value at 520 nm using UV 2450 visible spectrophotometer. The Leaf proline content was expressed in µg g^{-1} of leaf sample according to the following formula.

$$\mu \text{ moles of proline/g tissue} = \frac{\mu g \text{ proline / ml x ml toluene}}{115.5} \times \frac{5}{\text{g sample}}$$

where, 115.5 is the molecular weight of proline.

RESULTS AND DISCUSSION

In the present investigation, eleven genotypes *viz*., ICGV 07132, ICGV 0707, TCGS 1398, TCGS 1157, TCGS 1073, TCGS 1173, MLTG 4, Narayani, TPT 1, Kadiri 9 and Kadiri 6 were screened for moisture stress tolerance and subsequent recovery after reaching the permanent wilting point in pot culture experiment in rainout shelter (Figure 1).

In groundnut, maximum yield losses under drought situation coincide with pegging, pod formation and pod development stages (mid-season drought) commenced from 50- 80 DAS. The groundnut genotypes under study were categorized into three groups based on drought tolerance and recovery per cent upon watering after reaching permanent wilting point. Among the eleven genotypes analyzed, TCGS 1157 and MLTG 4 genotypes showed early recovery after reaching the permanent wilting point and were grouped into moisture stress tolerant group. In contrast Narayani and Kadiri 6 were highly sensitive to moisture stress and were grouped into moiture stress sensitive group and the remaining genotypes were grouped into intermediate types (Table 1). Puangbut *et al.*(2009) grouped six genotypes into four different groups based on yield response to pre-flowering drought and also reported that two genotypes *viz*., KK 60-3 and Tifton-8 had moiture stress tolerance with significant yield.

Among the genotypes, TCGS 1157 and MLTG 4 were found to be most drought tolerance and with highest percentage of survival even after reaching permanant wilting point. Based on this, the four contrasting groundnut genotypes *viz*., TCGS-1157, MLTG 4, Narayani and Kadiri 6 were considered for further studies of drought tolerance submitted to midseason moisture stress (50-80 DAS) in field conditions.

Morphological changes

Leaf folding

In response to moiture stress, groundnut exhibits leaf folding where the opposite leaflets of tetra foliate leaf comes together and orient parallel to each other and thereby reduce the evapotranspiration losses (Reddy *et al.,* 2003). The field was irrigated till it reached field capacity at 50 DAS. Prominent leaf folding was observed in drought tolerant genotypes such as TCGS 1157 and MLTG 4 (Figure 2) to reduce the evapotranspiration losses

within 15 days after moisture stress imposition (*i. e*., 65 DAS). In this process, the upper photosynthetically active region of opposite leaflets comes together and the lower surface of the leaflets was exposed to both solar and ground radiation (Chung *et al*., 1997). In contrast, drought sensitive genotypes like Kadiri 6 and Narayani did not exhibit leaf folding phenomenon resulted in withering and drooping of leaves at 65 DAS.

In resistant genotypes, the leaf folding helped them to reducing water loss and thereby sustained prolonged drought stress efficiently. The leaf folding characterized by moisture stress greatly contributes to adoptation to the adverse environmental condition (Nautiyal *et al*., 2008)

Root length

Water stress often stimulates the growth of roots into deeper layers of soil. The average root length of groundnut genotypes subjected to 30 days of water stress (50-80 DAS) was more in all the genotypes when compared to control (Table 1). The best way to measure the root length was through root structures and in this experiment the root length was underestimated as most of them were broken. Drought tolerant genotypes (TCGS 1157 and MLTG 4) displayed better ability to expand their roots than drought susceptible genotypes (Narayani and Kadiri 6) under moisture stress situation (Figure 3). It confirmed the ability of groundnut to deep rooting in soils with low water availability, in order to tolerate the water stress condition (Vorasoot *et al.*, 2003).

The results are in agreement with the fact that groundnut has the capacity to modify the root length and thereby exploiting the available water in deeper soil layers as an important mechanism to avoid drought (Songsri *et al*., 2008 and Kambiranda *et al.,* 2011). The extent and the pattern of root development were closely related to the ability of the plants to absorb water, enhancement of root growth under drought conditions allows the plant to extract more water from deeper zones may contribute to the drought tolerance in groundnut (Madhusudhan and Sudhakar, 2014).

Root shoot ratio

The groundnut genotypes under the study when subjected to midseason drought showed increased root: shoot ratio when compared to control (Table 2). The drought tolerant genotypes *viz*., TCGS 1157 and MLTG 4 showed increased root shoot ratio of 103 per cent and 79 per cent respectively over control (well watered). In drought susceptible genotypes (Narayani and Kadiri 6) also the root shoot ratio increased slightly (53% and 31 %) when compared to respective control. The extent of increase in root: shoot ratio is more in drought tolerant genotypes when compared to susceptible genotypes (Table 3). Root shoot ratio in groundnut under water stress directly related to changes in source and sink relationships with the root being a stronger sink than the shoots (Figure 4).

The increased root length and decreased shoot growth under water stress contributes to increased root shoot ratio. The results obtained with root shoot ratio in groundnut genotypes were in consistent with the fact that the plants which exhibits an increase in root shoot ratio under water stress were more drought tolerant (Lloret *et al.,*1999). This might be due to their ability to maintain osmotic pressure, ability to maximise available water and penetrate into deeper soil horizon.

The degree of reduction in shoot length under water stress may be due to decrease in cell division, elongation and enlargement which might have ultimately leads to the reduction in plant height (Madhusudhan and Sudhakar, 2014).

Proline content

With prolonged moisture stress imposition from 50 to 80 DAS, proline content was increased continuously at all sampling intervals in both drought tolerant and susceptible genotypes in comparison with their respective controls (Table 3). In drought tolerant genotypes like MLTG 4 and TCGS 1175, at 10 days after moisture stress imposition the proline content was 136.3 and 168.3 µg g^{-1} respectively. The accumulation of proline was increased significantly in these genotypes at 20 days (179 and 241µg g^{-1}) and 30 days (262 and 247 µg g^{-1}) after moisture stress imposition.

In drought susceptible genotypes like Kadiri 6 and Narayani, at 10 days after stress imposition the accumulation of proline content was 134 and 211µg g^{-1} respectively. The proline content was increased even more than drought tolerant genotypes at 20 days (288 and 322 µg g^{-1}) and 30 days (409 and 432 µg g^{-1}) after stress imposition in Kadiri 6 and Narayani respectively (Figure 5). The proline content accumulated in cells may contribute to the maintenance of turgor of cells and the drought sensitive genotypes were prone to loose moisture

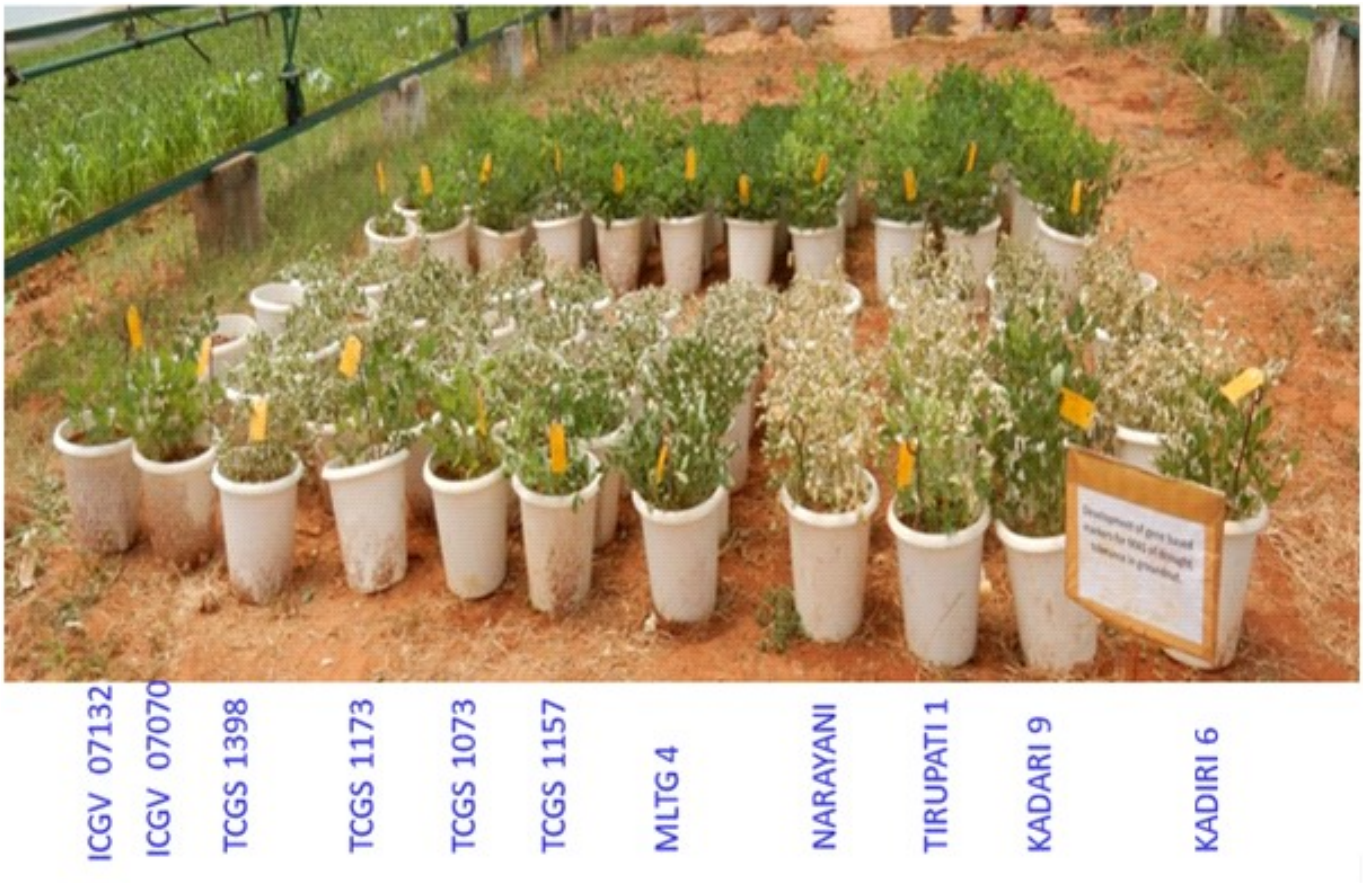

Fig. 1. Screening of groundnut genotypes for drought tolerance at 50 DAS in pot culture experiment in rainout shelter

A **B**

Fig. 2. Leaf folding displayed in MLTG 4(A) where as prominent drooping in Narayani at 60 DAS (10 days after moisture stress imposition)

Table 1. Root length contrasting groundnut genotypes at the time of harvest in both control and respective moisture stress

S. No.	Genotypes	Root length	
		Control (cm)	Stress (cm)
1	MLTG 4	13.5 ± 1.1	16 ± 1.5
2	TCGS 1157	13.4 ± 1.2	16 ± 2.5
3	NARAYANI	12 ± 0.83	15.2 ± 1.1
4	Kadiri 6	12.6 ± 1.1	14.8 ± 1.3

Table 2. Root shoot ratio of contrasting groundnut genotypes at the time of harvest in both control and respective moisture stress

S. No.	Genotypes	Root shoot ratio	
		Control	Stressed
1	MLTG 4	0.34	0.61
2	TCGS 1157	0.33	0.67
3	NARAYANI	0.36	0.55
4	K 6	0.38	0.50

Table 3. Proline content in contrasting groundnut genotypes at the time of harvest in both control and respective moisture stress

S. No.	Genotypes	50 DAS	60 DAS		70 DAS		80 DAS	
		Control	Control	Stressed	Control	Stressed	Control	Stressed
1	MLTG 4	10 ± 1.6	8.5 ± 0.6	136.6 ± 1.6	25.5 ± 2.5	179 ± 2.5	37.33 ± 1.5	262.7 ± 1.8
2	TCGS 1157	7.1 ± 1.07	16.1 ± 1.9	168.3 ± 1.6	26.1 ± 2.46	241.1 ± 12.0	39.9 ± 1.82	247.2 ± 5.3
3	NARAYANI	1.7 ± 0 .19	3.8 ± 0.96	211 ± 2.0	18 ± 3.3	322.8 ± 2.0	69 ± 1.66	432.7 ± 10.8
4	Kadiri 6	3.43 ±0.9	5.5 ± 0.9	134.9 ± 3.4	15.73 ± 0.4	288.3 ± 5.3	31.97 ± 0.15	409.6 ± 3.2

earlier than drought tolerant genotypes and thereby accumulated more proline under prolonged drought situation.

The proline accumulation in drought susceptible genotypes *viz*., Kadiri 6 and Narayani were increased in two folds than the drought tolerant genotypes *viz*., TCGS 1157 and MLTG 4 at prolonged moisture stress of 20 to 30 days. Accumulation of free proline content under moisture stress in groundnut genotypes was most probably due to higher rates of proline synthesis than proline oxidation (Ranganayakulu *et al.,* 2015).

Sensitive genotypes were subjected to severe stress at early stages as they did not show any water saving mechanisms like leaf folding which was prominent in drought tolerant genotypes. This leads to increased evapotranspiration rates in Kadiri 6 and Narayani and thereby synthesizes more proline to maintain osmotic potential. Therefore, the increased levels of proline under drought stress can be better considered as a stress indicator in plants (Kaneria and Bishi, 2015).

Similar results were reported by Ranganayakulu *et al.* (2015) in K-134 (drought tolerant) and JL-24 (drought susceptible) groundnut genotypes. In contrast to groundnut, increase in proline content was more in drought tolerant cowpea genotypes than in sensitive genotypes

CONCLUSION

Among the eleven genotypes analyzed under midseason drought, TCGS 1157 and MLTG 4 were found to be most drought tolerant and Narayani and Kadiri 6 were found to be highly sensitive to moisture stress.

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MANAGEMENT OF LEPIDOPTERAN PESTS OF SESAMUM WITH CERTAIN INSECTICIDES

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ABSTRACT

Field studies on management of lepidopteran insect pests of sesame with certain insecticides were carried out during *summer* 2017 at wet land farm, S. V. Agricultural College, Tirupati. Sesame crop (var., YLM-66) was sown on 7th March 2017 for evaluation of insecticides against sesame pests. Chlorantraniliprole @ 0.3 ml/L was found to be highly effective against *Antigastra catalaunalis* as well as *Acherontia styx.*

KEYWORDS: *Antigastra catalaunalis*, *Acherontia styx* and chlorantraniliprole.

INTRODUCTION

A total of 29 insect-pests have been reported infesting sesame crop at its various growth stages in India (Rai, 1976). Out of these only three species *viz.*, the til leaf webber and capsule borer, *Antigastra catalaunalis* Duponchel; til hawk moth, *Acherontia styx* Westwood and sesame gallfly, *Asphondylia sesami* Felt, were considered as major pests (Choudhary *et al.,* 1986). Among these, *A. catalaunalis* is reported to be the most serious pest causing yield losses up to 90 per cent (Ahuja and Bakhatia, 1995).

MATERIAL AND METHODS

A field experiment was conducted at the wet land farm, Sri Venkateswara Agricultural College, Tirupati during *summer* 2017 to evaluate the efficacy of certain new insecticides against lepidopteran pests of sesame.

Lay out

The experiment was laid out in a randomized block design with 11 treatments including untreated control and replicated thrice. The size of the individual plot was 5 m x 4 m. with spacing of 30 cm between the rows and 15 cm between the plants. All the recommended packages of practices were adopted in managing crop to maintain a good crop stand.

Sowing and agronomic practices

"YLM-66", a popular Sesame variety was sown on 7th March, 2017. Two seeds per hill were sown by dibbling. Gap filling was done a week after germination and thinning was completed ten days after sowing leaving one healthy seedling per hill, and the plots were irrigated as and when required.

Preparation of Spray Fluid

Measured quantity of the insecticide formulation was mixed with required quantity of water and stirred well to obtain the desired concentration of spray fluid. In case of wettable powders and suspension concentrates, required quantities were mixed with a little quantity of water and then the remaining quantity of water was added to obtain desired concentration and stirred well.

Test insecticides

Details of insecticides used in the experiment are given in Table 1.

Insecticidal application

Insecticide treatments included in this experiment were applied with hand held knapsack sprayer. Spraying was done during morning hours with care to prevent the drift of the spray fluid reaching the adjacent plots by keeping a screen in between the plots. The sprayer was cleaned with water before changing the insecticide treatment.

Method of observations

Insecticidal treatments were imposed during 50 per cent flowering season when the pest population has

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Table 1. Particulars of treatments used

Treatments	Chemical name	Trade name	Formulation	Dose/litre	Source of supply
T_1	Acephate	Asataf	75% SP	1.5 g L^{-1}	Rallis
T_2	Chlorpyriphos	Dhanwan	20% EC	2.5 ml L^{-1}	Dhanuka
T_3	Emamectin benzoate	Proclaim	5% SG	0.2 g L^{-1}	Syngenta
T_4	Lambda cyhalothrin	Karate	2.5% EC	1 ml L^{-1}	Syngenta
T_5	Dichlorvos	Doom	76% EC	1 ml L^{-1}	UPL
T_6	Chlorantraniliprole	Coragen	18.5% SC	0.3 ml L^{-1}	Dupont
T_7	Thiacloprid	Alanto	240 SC	0.3 ml L^{-1}	Bayer
T_8	Imidacloprid	Confidor	17.8 SL	0.3 ml L^{-1}	Bayer
T_9	Acetamiprid	IPRID	20% SP	0.2 g L^{-1}	Indocell
T_{10}	Pymetrozine	Chess	50 WG	0.4 g L^{-1}	Syngenta
T_{11}	Untreated control	-	-	-	-

reached ETL. During the period of study sesamum crop was attacked by different insect pests *viz.,* leaf webber, hawk moth, leaf hoppers, aphids. The counts of leaf webber larvae, hawk moth larvae were taken 24 hours before spraying, and on 1DAS, 3 DAS, 5 DAS and 7DAS. The population of all the pests were counted on 15 randomly selected plants.

Statistical Analysis

The per cent reduction of larval population was calculated by using modified Abbott's formula given by Fleming and Retnakaran (1985).

Per cent population reduction =

$$1-\left[\frac{\text{(Post treatment population in treatment}}{\text{Pre treatment population in treatment}}\times\frac{\text{Pre treatment population in check)}}{\text{Post treatment population in check}}\right]\times 100$$

The per cent values were transformed into angular values which were subjected to statistical analysis with the help of SPSS (SPSS, 2013).

RESULTS AND DISCUSSION

Management of leaf webber *Antigastra catalaunalis*

One day after spraying

At 1 DAS, treatment with pymetrozine @ 0.4 g/L (25.56 %) has given a significant per cent reduction in larval population followed by the rest of the treatments *viz.,* acetamiprid @ 0.2 g/L (25.00 %), emamectin benzoate @ 0.2 g/L (21.67 %), imidacloprid @ 0.3 ml/L (21.11 %), dichlorvos @ 1 ml/L (18.89 %), chlorpyriphos @ 2.5 ml/L (16.67 %), acephate @ 1.5g/L (15.56 %), thiacloprid @ 0.3 ml/L (13.89 %), chlorantraniliprole @ 0.3 ml/L (13.33 %), lambda cyhalothrin @ 1ml/L (11.11 %).

The order of efficacy of different treatments was as follows:

T_{10} > T_9 > T_3 > T_8 > T_5 > T_2 > T_1 > T_7 > T_4 > T_6 > T_{11}

Three days after spraying:

At 3 DAS, treatment with emamectin benzoate @ 0.2 g/L (69.44 %) has given a significant per cent reduction in larval population and followed by the rest of the treatments *viz.,* chlorpyriphos @ 2.5 ml/L (63.89 %), chlorantraniliprole @ 0.3 ml/L (63.33 %), lambda cyhalothrin @ 1ml/L (62.22 %), acephate @ 1.5g/L (57.22 %), thiacloprid @ 0.3 ml/L (55.00 %), imidacloprid @ 0.3 ml/L (48.33 %), While lowest per cent reduction was recorded in acetamiprid @ 0.2 g/L (32.78 %) followed by dichlorvos @ 1 ml/L (35.56 %) and pymetrozine @ 0.4 g/L (38.33 %).

The order of efficacy of different treatments is as follows:

$T_3 > T_2 > T_6 > T_4 > T_1 > T_7 > T_8 > T_{10} > T_5 > T_9 > T_{11}$

These results are comparable with the findings of Varma *et al.* (2013) who reported that emamectin benzoate 0.001 % recorded lowest flower and capsule damage of *Antigastra catalaunalis*

Five days after spraying

At 5 DAS, treatment with chlorantraniliprole @ 0.3 ml/L (93.33 %) has given a significant per cent reduction in larval population and was on par with lambda cyhalothrin @ 1ml/L (83.33 %), chlorpyriphos @ 2.5 ml/ L (80.00 %), emamectin benzoate @ 0.2 g/L (76.67 %), while, next effective treatments were acephate @ 1.5g/L (70.00 %) followed by dichlorvos @ 1 ml/L (68.89 %), thiacloprid @ 0.3 ml/L (67.78 %), imidacloprid @ 0.3 ml/L (46.67 %), pymetrozine @ 0.4 g/L (37.22 %). Lowest per cent reduction was recorded in acetamiprid @ 0.2 g/ L (28.33 %).

The order of efficacy of different treatments was as follows:

$T_6 > T_4 > T_2 > T_3 > T_1 > T_5 > T_7 > T_8 > T_{10} > T_9 > T_{11}$

Results of the present findings comparable with the findings of Sasikumar and Kumar (2015) who reported that treatment with lambda cyhalothrin, the per cent leaf damage of leaf webber was lowest and was superior than the other treatments.

Seven days after spraying

At 7 DAS, treatment with chlorantraniliprole @ 0.3 ml/L (93.33 %) has given a significant per cent reduction in larval population and was on par with lambda cyhalothrin @ 1ml/L (93.33 %), chlorpyriphos @ 2.5 ml/ L (93.33 %), emamectin benzoate @ 0.2 g/L (86.67 %), thiacloprid @ 0.3 ml/L (83.33 %), acephate @ 1.5g/L (83.33 %), dichlorvos @ 1 ml/L (81.11 %). The lowest per cent reduction was recorded in acetamiprid @ 0.2 g/ L (37.22 %), pymetrozine @ 0.4 g/L (47.22 %), imidacloprid @ 0.3 ml/L (52.22 %).

The order of efficacy of different treatments was as follows:

$T_6 = T_4 = T_2 > T_3 > T_7 > T_1 > T_5 > T_8 > T_{10} > T_9 > T_{11}$

The results after 7 DAS revealed chlorantraniliprole as an effective insecticide in reducing the larval population. Not much work has been done on use of Chlorantraniliprole on insect pests of sesame. Hence work on Chlorantraniliprole on other lepidopteran insects were considered here for discussion.

The results of the present investigations are in accordance with Duraimurugan and Lakshminarayana (2014) who reported that Chlorantraniliprole were very effective in suppressing the larval population of Castor semilooper *Achaea janata* during 2012 and tobacco caterpillar *Spodoptera litura* (0.0 to 0.1 and 0.0 to 0.3 larva/plant, respectively) during 2013 and significantly superior to emamectin benzoate and lufenuron (0.1 to 0.7 and 0.7 to 3.3 larvae/plant, respectively) and untreated control (1.9 to 2.4 and 4.3 to 5.3 larvae/plant, respectively). These results are supported by Sreekanth *et al.* (2015) who reported that pod damage due to legume pod borer in pigeonpea was lowest in chlorantraniliprole. The present findings were in accordance with Jakhar *et al.* (2016) who reported that chlorantraniliprole 18.5 SC @ 0.15 ml/l of water gave maximum control of pod borers of pigeonpea (3.33%).

Management of hawk moth, *Acherontia styx*

One day after spraying

At 1 DAS, treatment with chlorantraniliprole @ 0.3 ml/L (40.00 %) has given a significant per cent reduction in larval population followed by imidacloprid @ 0.3 ml/ L (23.33 %), lambda cyhalothrin @ 1 ml/L (23.33 %), acephate @ 1.5g/L (20.00 %), dichlorvos @ 1 ml/L (20.00 %), pymetrozine @ 0.4 g/L (20.00 %), emamectin benzoate @ 0.2 g/L (16.67 %), chlorpyriphos @ 2.5 ml/ L (16.67 %). The lowest per cent reduction was recorded in acetamiprid @ 0.2 g/L (13.33 %) and thiacloprid @ 0.3 ml/L (13.33 %).

The order of efficacy of different treatments was as follows:

$T_6 > T_8 = T_4 > T_1 = T_5 = T_{10} > T_3 = T_2 > T_9 = T_7 > T_{11}$

Three days after spraying

At 3 DAS, though lambda cyhalothrin @ 1ml/L (66.67 %) has given more per cent reduction in larval population, no significant differences were observed among treatments.

Effect of insecticides on per cent reduction of *Antigastra catalaunalis* larval population during *summer* 2017

Treatments	Dose	Pre counts per 15 plants	Per cent reduction of larval population			
			1 DAS	3 DAS	5 DAS	7 DAS
T_1 : Acephate	1.5 g L^{-1}	30	15.56^{ab} (14.35)	57.22^{abc} (51.29)	70.00^{ab} (63.00)	83.33^{a} (75.00)
T_2 : Chlorpyriphos	2.5 ml L^{-1}	33	16.67^{ab} (15.00)	63.89^{ab} (57.29)	80.00^{a} (72.00)	93.33^{a} (84.00)
T_3 : Emamectin Benzoate	0.2 g L^{-1}	28	21.67^{a} (21.00)	69.44^{a} (62.64)	76.67^{a} (70.00)	86.67^{a} (78.00)
T_4 : Lambda cyhalothrin	1 ml L^{-1}	31	11.11^{ab} (10.70)	62.22^{abc} (56.35)	83.33^{a} (75.00)	93.33^{a} (84.00)
T_5 : Dichlorvos	1 ml L^{-1}	34	18.89^{ab} (17.35)	35.56^{bc} (32.35)	68.89^{ab} (61.29)	81.11^{a} (72.64)
T_6 : Chlorantraniliprole	0.3 ml L^{-1}	33	13.33^{ab} (13.05)	63.33^{abc} (58.00)	93.33^{a} (84.00)	93.33^{a} (84.00)
T_7 : Thiacloprid	0.3 ml L^{-1}	34	13.89^{ab} (13.35)	55.00^{abc} (50.00)	67.78^{ab} (60.64)	83.33^{a} (75.00)
T_8 : Imidachloprid	0.3 ml L^{-1}	31	21.11^{ab} (19.70)	48.33^{abc} (44.00)	46.67^{bc} (43.00)	52.22^{b} (48.35)
T_9 : Acetamiprid	0.2 g L^{-1}	34	25.00^{a} (25.11)	32.78^{c} (29.64)	28.33^{c} (26.00)	37.22^{b} (33.29)
T_{10} : Pymetrozine	0.4 g L^{-1}	31	25.56^{a} (24.40)	38.33^{bc} (35.00)	37.22^{c} (33.29)	47.22^{b} (42.29)
T_{11} : Untreated Control	-	39	0.00^{b} (0.00)	0.00^{d} (0.00)	0.00^{d} (0.00)	0.00^{c} (0.00)

DAS = Days after spraying
Values followed by same letters are not significantly different as per DMRT at 0.05.
Values in parenthesis are angular transformed values.

Effect of insecticides on per cent reduction of *Acherontia styx* larval population during *summer* 2017

Treatments	Dose	Pre counts per 15 plants	Per cent reduction of larval population			
			1 DAS	3 DAS	5 DAS	7 DAS
T_1 : Acephate	1.5 g L^{-1}	17	20.00^{ab} (18.00)	46.67^{a} (42.00)	56.67^{a} (51.00)	73.33^{a} (72.00)
T_2 : Chlorpyriphos	2.5 ml L^{-1}	17	16.67^{ab} (15.00)	36.67^{a} (33.00)	50.00^{a} (45.00)	63.33^{a} (63.00)
T_3 : Emamectin Benzoate	0.2 g L^{-1}	18	16.67^{ab} (15.00)	63.33^{a} (57.00)	73.33^{a} (66.00)	73.33^{a} (72.00)
T_4 : Lambda cyhalothrin	1 ml L^{-1}	17	23.33^{ab} (21.00)	66.67^{a} (60.00)	70.00^{a} (63.00)	80.00^{a} (72.00)
T_5 : Dichlorvos	1 ml L^{-1}	14	20.00^{ab} (18.00)	33.33^{a} (30.00)	50.00^{a} (45.00)	66.67^{a} (60.00)
T_6 : Chlorantraniliprole	0.3 ml L^{-1}	12	40.00^{a} (36.00)	53.33^{a} (48.00)	60.00^{a} (54.00)	60.00^{a} (54.00)
T_7 : Thiacloprid	0.3 ml L^{-1}	15	13.33^{ab} (12.00)	36.67^{a} (33.00)	50.00^{a} (45.00)	73.33^{a} (72.00)
T_8 : Imidachloprid	0.3 ml L^{-1}	14	23.33^{ab} (21.00)	56.67^{a} (51.00)	66.67^{a} (60.00)	66.67^{a} (66.00)
T_9 : Acetamiprid	0.2 g L^{-1}	17	13.33^{ab} (12.00)	40.00^{a} (36.00)	66.67^{a} (60.00)	73.33^{a} (66.00)
T_{10} : Pymetrozine	0.4 g L^{-1}	16	20.00^{ab} (18.00)	53.33^{a} (48.00)	56.67^{a} (51.00)	73.33^{a} (72.00)
T_{11} : Untreated Control	-	23	0.00^{b} (0.00)	0.00^{b} (0.00)	0.00^{b} (0.00)	0.00^{b} (0.00)

DAS = Days after spraying
Values followed by same letters are not significantly different as per DMRT at 0.05.
Values in parenthesis are angular transformed values.

Five days after spraying

At 5 DAS, though emamectin benzoate @ 0.2 g/L (73.33 %) has given more per cent reduction in larval population, no significant differences were observed among treatments.

Seven days after spraying

At 7 DAS, though treatment with lambda cyhalothrin @ 1ml/L (80.00 %), has given a more per cent reduction in larval population followed no significant differences were observed among treatments.

CONCLUSIONS

Among all the insecticides tested, Chlorantraniliprole 18.5% SC at 0.3 ml/L has given a successful reduction in larval population of both *Antigastra catalaunalis* and *Acherontia styx*. In case of *A. Catalaunalis* this reduction was evident even after 7 of spraying which indicates the long residual action of Chlorantraniliprole.

Chlorantraniliprole is a new compound by DuPont belonging to a new class of selective insecticides (anthranilic diamides) featuring a novel mode of action (group 28 in the IRAC classification). By activating the insect ryanodine receptors (RyRs) it stimulates the release and depletion of intracellular calcium stores from the sarcoplasmic reticulum of muscle cells, causing impaired muscle regulation, paralysis and ultimately death of sensitive species (Cordova *et al.,* 2006). It has also been reported that because of its unique mode of action, chlorantraniliprole treated insects stops feeding within 30 minutes of treatment thus proving as an effective chemical for the management of defoliators such as *Spodoptera exigua, Plutella xylostella* and others (Hannig *et al.,* 2009). This was further confirmed in the present investigation, significantly high larval mortality of *Acherontia styx* was within 24 hrs of treatment (Table 2).

Chlorantraniliprole is a systemic insecticide and travels mainly through xylem and moves throughout the green tissue of plants (Lahm *et al.,* 2007). Because of this systemic nature, Chlorantraniliprole has a long residual effect and manage the insect pest population up to 7 days after spraying, which is also evident from the present work on *A. Catalaunalis* (Table 1). Adams *et al*. (2016) have reported that Chlorantraniliprole and flubendiamide provided long residual mortality of corn earworm when applied at the R3 growth stage. However, the authors are of the opinion that the persistence of these insecticides on crop tissues may accelerate the likelihood of resistance development because multiple generations of insect pests will likely be exposed to lethal concentrations from a single application, thereby increasing selection pressure.

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EFFECT OF VARIOUS ORGANIC MANURES ON SOIL PHYSICAL, PHYSICO CHEMICAL PROPERTIES AND PRODUCTIVITY OF RAINFED GROUNDNUT (*Arachis hypopaea* L.)

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ABSTRACT

The soil of the experimental field was red sandy loam (Haplustalf). The experiment had six treatments each replicated four times in a randomized block design and four different sources of organic manures viz., FYM @ 10 t ha^{-1}, vermicompost @ 2.5 t ha^{-1}, poultry manure @ 4 t ha^{-1} and pressmud cake @ 10 t ha^{-1}were evaluated and compared with recommended dose of fertilizers and control (without fertilizers). The physical properties *viz*., bulk density, porosity and water holding capacity were significantly influenced by application of various organic manures. FYM application @ 10 t ha^{-1} recorded the lowest bulk density (1.18 Mg m^{-3}), highest porosity (51.2 %) and highest water holding capacity (40.1 %) followed by pressmud cake application @ 10 t ha^{-1} and the lowest was recorded in control. The pH of the soil was significantly influenced by different treatments whereas the electrical conductivity of the soil was not influenced by the application of organic manures. The build up of organic carbon was recorded with the application of various organic manures. The highest organic carbon percent (0.51 %) was recorded in FYM application and the lowest was in control (0.30 %) and RDF (0.30 %). The pod yield was significantly influenced by the application of various organic manures. The higher pod yield was recorded in RDF (1531 kg ha^{-1}) which was on par with FYM (1470 kg ha^{-1}), poultry manure (1454 kg ha^{-1}), pressmud cake (1446 kg ha^{-1}) and vermicompost (1418 kg ha^{-1}) applications and the lowest was recorded in control (1188 kg ha^{-1}). The study indicated that FYM and pressmud cake applications were most effective in maintaining soil physical and physico-chemical properties apart from sustaining groundnut productivity and were on par with chemical fertilizers.

KEYWORDS: Organic manures, physical and chemical properties groundnut.

INTRODUCTION

Healthy soil is a basic requisite for the integrity of terrestrial ecosystems to remain intact and to recover from disturbances such as drought, climate change, pest infestation, pollution and human exploitation through agriculture. Deterioration of soil, and thereby soil health, is of great concern for human, animal and plant health (Wang and Chao, 1995). For centuries, organic manure has been recognized as a soil builder because of its contributions to improving soil quality. Organic manure applications improved soil physical properties through increased soil aggregation, improved aggregate stability, decrease in the volume of micropores while increasing macropores, saturated hydraulic conductivity and water infiltration rate, and soil water holding capacity at both field capacity and wilting point (Sulfab, 2013). Although, the accumulation of SOM through applied organic manures depends upon the rate of decomposition process. Organic manures and compost applications resulted in higher SOC content, soil pH and electrical conductivity (Sankaranarayanan, 2004).

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of India. It is cultivated in 5.95 m ha with a production of 7.54 million tonnes at a productivity of 1268 kg ha^{-1} (Anonymous, 2015). Groundnut being a legume crop, leaves lot of residual fertility which inturn helps the succeeding crop under rainfed farming situations. Further, integration and incorporation of organic manures (farmyard manure, vermicompost etc.) helps to improve soil structure, soil microbial activity and soil moisture conservation, which inturn helps to stabilize the production and productivity of the crops (Lourduraj, 1999). Among the different agronomic management practices, use of organics is of prime importance under rainfed farming situations (Nagaraj *et al.,* 2001).Keeping the above aspects in view, an experiment on evaluation of different organic sources on different soil properties and yield of groundnut was chosen.

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MATERIAL AND METHODS

An experiment on evaluation of different organic manures on soil health and productivity of rainfed groundnut was started in the year 2007 at Regional Agricultural Research Station, Tirupati, Acharya N. G Ranga Agricultural University, Andhra Pradesh. The same experiment was selected for the present study during *kharif*-2016 with the prime objective of monitoring the soil health. The experiment involves six treatments each replicated four times in a randomized block design.The treatments include T_1 : Control (no manure or fertilizers), T_2 : RDF @ 20:40:50 N : P_2O_5 : K_2O kg ha^{-1}, T_3 : Vermicompost @ 2.5 t ha^{-1} , T_4 : Poultry manure @ 4 t ha^{-1}, T_5 : Farm yard manure @ 10 t ha^{-1} , T_6 : Pressmud cake @ 10 t ha^{-1}.

Fully decomposed organic manures were applied to the plots as per the treatments before sowing. Fertilizers *viz.,* N @ 20 kg ha^{-1} as urea, P_2O_5 @ 40 kg ha^{-1} as single super phosphate and K_2O @ 50 kg ha^{-1} as murate of potash were applied to the RDF treatment in lines at a depth of 5 cm in the furrows made with hand hoes 5 cm away from the seed rows. Surface soil samples were collected before sowing and at harvest of the crop. The collected soil samples were mixed separately, dried under shade, pounded to pass through 2 mm sieve and labelled and were analysed for soil properties (Table 1). The crop was harvested andpod yield, haulm yield, harvest index, 100 pod weight, 100 kernel weight, shelling percentage and plant population were recorded at harvest. The soil bulk density, porosity and water holding capacity was determined by Keen Raczkowski method (Baruah and Barthakur, 1997). The soil pH, EC and organic carbon were determined by Jackson(1973), Richards *et al.* (1954) and Walkley and Black (1934) wet oxidation method respectively. Data was analyzed statistically for test of significance following the Fisher's method of analysis of variance as outlined by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The results on effects of application of various organic manures on soil physical and physico-chemical properties are discussed and presented in Table 1.

Soil bulk density, porosity and water holding capacity at harvest were significantly influenced by the application of different organic manures. The bulk density of the soil at harvest ranged from 1.18 to 1.29 Mg m^{-3} with an overall mean of 1.25 Mg m^{-3}. Soil bulk density decreased with the application of organic manures. Significantly lower bulk density (1.18 Mg m^{-3}) was recorded in FYM application @ 10 t ha^{-1} than control and RDF and was found on par with pressmud cake application @ 10 t ha^{-1}(1.20 Mg m^{-3}). Highest bulk density was recorded in control (1.29 Mg m^{-3}).The lower bulk density in FYM and pressmud cake applications might be due to increased organic matter addition, which binds the soil particles together and increases the porosity which inturn increases soil volume. The results were in accordance with Prakash *et al*. (2002) reported in an Alfisol that soil bulk density decreased in treatment with FYM as compared to the treatments with vermicompost, processed compost, control and chemical fertilizers. They also reported that the decrease in bulk density with FYM was higher in second year compared to previous year.

Porosity of the soil at harvest ranged from 45.6 % to 51.2 % with an overall mean of 48.9 %. Soil porosity increased with the application of organic manures and significantly higher porosity (51.2 %) was recorded in FYM application than control and RDF and was found on par with pressmud cake application (50.2 %). The lowest porosity was recorded in control (45.6 %) followed by RDF (47.2), poultry manure @ 4 t ha^{-1}(49.7 %) and vermicompost @ 2.5 t ha^{-1} application (49.2 %). The higher porosity in FYM and pressmud cake applied treatments might be due to increased organic matter addition, which binds the soil particles together and increases the porosity. The results were in accordance with Mahimairaja *et al*. (1986). Rasool *et al*. (2008) reported that FYM significantly increases the porosity when compared with control and RDF treatment.

Water holding capacity of the soil at harvest ranged from 28.1 to 40.1 % with an overall mean of 33.5 %. The water holding capacity increased with the application of organic manures. Significantly higher water holding capacity was recorded in FYM application (40.1 %) than control and RDF and was found on par with pressmud cake application (37.6 %). Lowest water holding capacity was recorded in control (29.02 %) followed by RDF (28.1 %), poultry manure (35.8 %) and vermicompost applications (30.2 %).The higherwater holding capacity in FYM and pressmud cake applied treatments might be attributed to increased organic matter, increased porosity and decreased bulk density as the water holding capacity is determined by these factors. Brown and cotton (2011) reported that water holding capacity increases 1.57 times

Table 1. Effect of application of various organic manures on soil physical and physico-chemical properties at harvest of groundnut during current crop season

(Mean value of four replications)

Treatments	B.D (Mg m^{-3})	Porosity (%)	WHC (%)	pH	EC (dS m^{-1})	OC (%)	Pod yield (kg ha^{-1})
Control	1.29	45.60	29.02	6.42	0.06	0.30	1188
RDF @ (20:40:50 N:P:K kg ha^{-1})	1.28	47.20	28.10	6.52	0.07	0.30	1531
Vermicompost @ 2.5 t ha^{-1}	1.27	49.20	30.20	6.80	0.07	0.34	1418
Poultry manure @ 4 t ha^{-1}	1.25	49.70	35.80	7.20	0.09	0.45	1454
FYM @ 10t ha^{-1}	1.18	51.20	40.10	7.13	0.11	0.51	1470
Press mud cake @ 10 t ha^{-1}	1.20	50.20	37.60	6.88	0.06	0.48	1446
Mean	1.25	48.90	33.50	6.82	0.08	0.40	1417
SE.m.±	0.01	0.40	0.97	0.06	0.01	0.02	95
C.D (p = 0.05)	0.03	1.20	2.92	0.18	NS	0.06	269

in all treatments receiving organic manures when compared with control in a treatment conducted on changes in soil properties and carbon content following compost application.

Soil pH and organic carbon content were significantly influenced by the application of various organic manures whereas electrical conductivity was not significantly influenced. Soil pH at harvest stage ranged from 6.42 to 7.20 with an overall mean of 6.82. The pH increased with the application of organic manures. Significantly higher pH was recorded in poultry manure application (7.20) than control and RDF and was found on par with the FYM application (7.13). lowest pH was recorded in control (6.42) followed by RDF (6.52), vermicompost (6.80) and pressmud cake applications (6.88).The mechanism responsible for this increase in soil pH was due to ion exchange reactions which occur when terminal OH^- of Al or Fe^{2+} hydroxyl oxides are replaced by organic anions which are decomposition products of the manure such as malate, citrate and tartrate (Bessho and Bell, 1992; Van *et al*., 1996; Pocknee and Summer, 1997; Hue and Amiens, 1989). Magagula *et al*. (2010) found that soil pH was highest in poultry manure application (5.7) and it was on par with FYM application (5.66), when compared with control (5.5) and RDF (5.2) while evaluating effects of chicken manure on soil properties under sweet potato culture in Swaziland.

EC of the soil at harvest ranged from 0.06 to 0.11 dS m^{-1} with an overall mean of 0.08 dS m^{-1}. EC was not significantly increased with the application of organic manures. However, slight increase in EC was recorded with the treatments receiving organic manures. Highest EC was recorded in FYM application (0.11 dS m^{-1}) followed by poultry manure (0.09 dS m^{-1}) and vermicompost applications (0.07 dS m^{-1}) which was on par with RDF (0.07 dS m^{-1}). The lowest EC was reported in control(0.06 dS m^{-1}) and pressmud cake application (0.06 dS m^{-1}).The slight increase in EC might be due to organic manures does not contain salts and hence there was no influence of organic manure salt accumulation in soil (Bajpai *et al*., 1980). The results were in accordance with Verma *et al*. (2015) who reported that the variation between treatment means was not statistically significant from low to standard EC. EC did not differ significantly with the application of different sources and doses of organic manures, including FYM (Chawala and Chhabra, 1991; Stalin *et al*., 2006).

Soil organic carbon of the soil at harvest ranged from 0.30 % to 0.51 % with an overall mean of 0.40 %. The organic carbon content increased in the soil with the application of organic manures. Significantly higher organic carbon was observed in FYM application (0.51 %) than control and RDF and was found on par with the pressmud cake (0.48 %) and poultry manure applications (0.45 %). Lowest organic carbon content was reported in

control (T_1) (0.30 %), RDF(0.30 %) and vermicompost applications (0.34 %).This might be due to the residual effect of organic manures on soil which increases organic carbon content as reported by Wong *et al*. (1999). The increase in soil organic carbon was quite obvious due to reason that carbonaceous materials contribute to soil organic carbon after their decomposition (Basita *et al*., 2013).Gathala *et al*. (2007) reported that the application of FYM @ 20 t ha^{-1} recorded highest organic carbon content when compared with same quantities poultry manure and vermicompost.

The yield attributes viz., 100 pod weight, 100 kernel weight, shelling percentage and plant population of groundnut of the experimental field were not significantly influenced by the application of organic manures.

The pod yield of groundnut at harvest was significantly influenced by the application of different organic manures. Pod yield of groundnut at harvest ranged from 1188 to 1531 kg ha^{-1} with a mean value of 1417 kg ha^{-1}. Significantly higher pod yield of groundnut was recorded in RDF (1531 kg ha^{-1}) than control and was found to be on par with vermicompost (1418 kg ha^{-1}), poultry manure (1454 kg ha^{-1}), FYM (1470 kg ha^{-1}) and pressmud cake applications (1446 kg ha^{-1}). Lowest pod yield was recorded in control (1188 kg ha^{-1}). The higher pod yield obtained with RDF treated plot might be attributed to the adequate and balanced supply of the nutrients like N, P, K to meet the nutritional requirements of crop growth. Bhosanle and Pisal (2017) reported that recommended dose of fertilizers (RDF) shows significantly increased pod yield (35.42 q ha^{-1}) followed by FYM (33.01 q ha^{-1}), vermicompost (27.92 q ha^{-1}) and the lowest was recorded control (22.30 q ha^{-1}) in the study conducted on effect of nutrient management strategies on productivity of summer groundnut.

CONCLUSION

From this experiment, it could be concluded that organic manures *viz.,*FYM and pressmud cake applications were found most effective in maintaining soil physical and physico-chemical properties and sustaining groundnut productivity on par with chemical fertilizers. Depending on the availability, any of the organic manures *viz.,* FYM or pressmud cake @ 10 t ha^{-1} can be recommended for maintaining pod yield and soil health to promote organic farming in groundnut crop.

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EFFECT OF ANTI OXIDANT ENZYMES UNDER IRON DEFICIENCY STRESS CONDITIONS IN GROUNDNUT

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ABSTRACT

A pot culture experiment was conducted at Regional Agricultural Research Station (RARS) farm, S.V. Agricultural College, Tirupati campus of Acharya N .G. Ranga Agricultural University, during *kharif*, 2016 with factorial RBD design involving normal and calcareous soil. Twenty groundnut genotypes were tested for iron deficiency chlorosis tolerance at three (30, 60 and 90 DAS) different stages of growth. Enzymatic activities of certain antioxidant enzymes such as superoxide dismutase, peroxidase and catalase were altered under iron deficiency stress conditions. The results revealed that iron efficient groundnut genotypes had higher peroxidase and catalase activity and higher active iron content than inefficient groundnut genotypes. Among the antioxidant enzymes, super oxide dismutase activity was high under iron deficiency stress conditions. Significant decrease in peroxidase and catalase activity was observed at later growth stages due to increase in iron deficiency as was evident by decrease in active iron content. There was a strong and positive correlation between leaf peroxidase activity and leaf ferrous iron content.

KEYWORDS: Iron deficiency chlorosis (IDC), active iron, peroxidase, catalase and superoxide dismutase.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the second most important oilseed crop in India, which is mainly grown in states like Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra. Groundnut is an important source of edible oil and proteins. Groundnut and groundnut oil also contains cardiovascular protective properties (Stephens *et al*., 2010). Fe is essential for all living organisms and crucial for a variety of functions (Kobayashi *et al.,* 2012).

In India, groundnut occupies an area of 4.8 m ha with a production of 7.4 m t and with a productivity of 1552 kg ha^{-1}. In Andhra Pradesh, groundnut occupies an area of 0.87 m ha with a production of 0.5 m t and productivity of 564 kg ha^{-1} (Anonymous, 2014).

Iron is constituent of heme compounds such as cytochromes, peroxidase, and catalase, phytoferritin and ferredoxin. Iron deficiency is commonly observed in calcareous soils, but it is major concern in groundnut as the crop is highly susceptible to deficiency which affects economic yields especially under irrigated conditions. As calcareous soils are deficient in available iron (Fe^{2+}), iron deficiency chlorosis (IDC) is more prevalent in these soils. Cultivation of Iron Deficiency Chlorosis (IDC) resistant cultivars in calcareous soils is the aim of present study, which economically feasible and sustainable approach compared to application of iron containing fertilizers through soil or foliar spray.

MATERIALS AND METHODS

In the present study, 20 advanced groundnut breeding lines were evaluated in a pot culture experiment using factorial RBD and replicated thrice in calcareous and normal soil at Regional Agricultural Research Station farm, S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University. Genotypes were assessed for antioxidant enzymes (peroxidase, catalase and superoxide dismutase) and active iron at different stages of crop growth (30, 60 and 90 DAS).

Estimation of Superoxide dismutase (SOD)

Superoxide dismutase was estimated using the method given by Fridovich (1975). One gram of fresh leaf sample was taken and ground with 10 ml of potassium phosphate buffer. The grounded leaf sample was centrifuged at 10,000 rpm for 10 min at 4°C. After centrifugation the supernatant was collected and refrigerated. 50 µl of enzyme extract was added to test tubes containing 600 µl of potassium phosphate buffer, 60 µl of ethylene diamine tetra acetic acid, 390 µl of methionine, 0.6 µl of riboflavin and 300 µl of nitro blue

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tetrazolium chloride. Along with the sample test tubes, blank (without nitro blue tetrazolium chloride and enzyme extract) and reference (without enzyme extract) were also maintained. The sample, reference and blank tubes were kept under fluorescent light for 15 min and absorbance was recorded at 560 nm and expressed as units g^{-1}(fr.wt) min^{-1}. One unit is defined as change in absorbance per gram fresh weight per minute.

Estimation of Catalase (CAT)

Catalase was estimated by grinding 300 mg of leaf tissue with 2.5 ml of sodium phosphate buffer and 1 ml of 1% poly vinyl pyrrolidine. The grounded sample was centrifuged at 10,000 rpm for 15 min at 4°C. The supernatant was collected after centrifugation and refrigerated. 50 µl of enzyme extract was added to test tube containing 2 ml of sodium phosphate buffer and 950 µl of hydrogen peroxide solution. Besides this, blank was also run without the enzyme extract. Absorbance was recorded at 240 nm and expressed as units g^{-1}(fr.wt) min^{-1}. One unit is defined as change in absorbance per gram fresh weight per minute. The estimation was carried out as per the method given by Sadasivam and Manickam (1992).

Estimation of Peroxidase (POD)

Peroxidase was estimated as per the method given by Mahadevan and Sridhar (1986). One gram of fresh leaf sample was taken and ground with 3 ml of sodium phosphate buffer. The grounded sample was subjected to centrifugation at 18000 rpm for 15 min at 5°C. After centrifugation the supernatant was collected and 0.1 ml of this supernatant was added to test tube containing 3 ml of sodium phosphate buffer, 50 µl of guaiacol solution and 30 µl of hydrogen peroxide solution. Blank is maintained without the enzyme extract and absorbance was recorded at 436 nm and expressed as units g^{-1}(fr.wt) min^{-1}. One unit is defined as change in absorbance per gram fresh weight per minute.

Estimation of Active iron (Fe^{+2})

For extracting ortho-phenanthroline extractable iron, third fully opened leaf from top was taken. Ortho-phenanthroline extractable iron in leaf sample was estimated as per Katyal and Sharma (1980).

For this estimation two grams of fresh leaf sample from was taken, washed with diluted HCl followed by glass distilled water and the adhering moisture was removed by sandwiching between absorbent papers. Then the leaf sample was chopped into fine bits and treated with 20 ml ortho-phenanthroline extract (p^H 3.0) and was allowed to stand for 16 hours. The Fe^{+2} was determined in the filtrate by reading the transmittancy at 510 nm in spectrophotometer.

RESULTS AND DISCUSSION

The active iron content in the present investigation increased from 30 to 60 DAS and decreased at 90 DAS of crop growth (Table 1). The active iron content showed significant differences among the soil types, genotypes and their interactions.

Singh (1994) has reported that active iron is taken as criterion and observed lower active iron in chlorotic plants. The ferrous iron content in iron efficient groundnut genotypes was higher than the susceptible genotypes due to less chlorosis. There was a comparatively less reduction in active Fe from normal to Fe-deficit soil among resistant compared to susceptible groundnut genotypes confirming its direct role in IDC resistance as Fe is required for chlorophyll formation and photosynthesis (Zheng, 2010).

The activities of peroxidase, catalase and superoxide dismutase showed highly significant differences among the soil types, genotypes and their interactions. The activities of peroxidase (Table 2) and catalase (Table 3) in the present investigation was higher at 30 DAS and decreased from 60 to 90 DAS. Higher decrease of peroxidase at later stages of crop growth was due to increase in iron deficiency as was evident by decrease in active iron content. Similar results were obtained by Nagaratnamma *et al*. (2011) and Sanjana (2004).The peroxidase, catalase and among the genotypes showed significant differences evident from higher mean values. The activities of peroxidase and catalase was higher in the groundnut genotypes TCGS-1624 and TCGS-1616 and lowest in groundnut genotypes TCGS-1613 and TCGS-1609 compared to other genotypes

Reduction in peroxidase and catalase activity was observed among all genotypes in iron deficient soil (calcareous soil) compared to iron sufficient soil. However, a lower reduction was observed among resistant genotypes compared to susceptible ones probably due to comparatively higher active-Fe maintained in leaves under Fe-stress conditions. A strong and positive correlation was observed between peroxidase activity and leaf iron content. Iron deficiency has been found to reduce

Table 1. Evaluation of groundnut genotypes for Active iron content (ppm) in iron sufficient and iron deficient soil conditions

S. No.	Genotypes	30 DAS			60 DAS			90 DAS		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS-1602	8.79	7.21	8.00	10.13	9.58	9.85	8.40	6.93	7.67
2	TCGS-1603	8.64	7.17	7.90	9.83	9.26	9.55	8.34	6.85	7.60
3	TCGS-1609	8.59	6.92	7.75	9.77	8.87	9.32	8.33	6.76	7.55
4	TCGS-1611	8.82	7.44	8.13	10.26	9.76	10.01	8.44	7.12	7.78
5	TCGS-1613	8.34	6.81	7.57	9.57	8.42	8.99	8.25	6.73	7.49
6	TCGS-1616	13.01	12.27	12.64	15.73	13.46	14.59	12.38	11.73	12.06
7	TCGS-1621	10.50	9.48	9.99	15.44	11.81	13.63	9.34	8.85	9.10
8	TCGS-1622	9.87	8.98	9.43	13.81	11.36	12.59	9.23	7.88	8.55
9	TCGS-1623	10.15	9.10	9.62	14.00	11.45	12.73	9.27	7.95	8.61
10	TCGS-1624	13.52	12.71	13.12	16.07	14.74	15.40	12.85	11.99	12.42
11	DHARANI	8.89	7.64	8.27	10.43	10.13	10.28	8.57	7.26	7.91
12	K6	9.00	7.97	8.49	11.86	10.65	11.25	8.73	7.51	8.12
13	NARAYANI	9.73	8.91	9.32	13.45	11.22	12.34	9.15	7.78	8.46
14	TAG-24	9.68	8.75	9.21	13.18	11.15	12.17	9.09	7.75	8.42
15	GREESHMA	9.08	8.20	8.64	12.27	10.77	11.52	8.78	7.59	8.19
16	TCGS-1511	10.35	9.21	9.78	14.45	11.66	13.06	9.30	8.10	8.70
17	TCGS-1514	9.29	8.65	8.97	12.86	10.95	11.91	8.97	7.69	8.33
18	TCGS-1517	9.32	8.43	8.88	12.52	10.86	11.69	8.93	7.63	8.28
19	TCGS-1522	8.93	7.89	8.41	11.23	10.48	10.85	8.69	7.44	8.06
20	TCGS-1528	8.96	7.76	8.36	10.93	10.32	10.62	8.61	7.35	7.98
	Mean	9.67	8.57		12.39	10.84		9.18	7.95	
		CD(P=0.05)	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**
	T	0.03	0.01		0.0348	0.0123		0.0214	0.0076	
	G	0.0913	0.0324	6.6	0.11	0.039	5.9	0.0678	0.0241	6.2
	T×G	0.129	0.0459		0.155	0.0552		0.096	0.0341	

T_1: Iron Sufficient Soils; T_2: Iron Deficient Soils (Calcareous Soils); NS: Non Significant

Table 2. Evaluation of groundnut genotypes for Peroxidase activity (units g^{-1}(fresh wt) min^{-1}) in iron sufficient and iron deficient soil conditions

S. No.	Genotypes	30 DAS			60 DAS			90 DAS		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS-1602	9.45	6.56	8.01	3.15	2.86	3.01	2.75	2.13	2.44
2	TCGS-1603	8.65	6.52	7.59	3.12	2.75	2.94	2.74	2.07	2.41
3	TCGS-1609	8.64	6.37	7.51	3.07	2.65	2.86	2.65	1.92	2.29
4	TCGS-1611	9.33	6.89	8.11	3.24	2.95	3.10	2.78	2.24	2.51
5	TCGS-1613	8.46	5.35	6.91	3.03	2.53	2.78	2.30	1.85	2.08
6	TCGS-1616	15.74	11.08	13.41	4.48	4.18	4.33	3.67	3.51	3.59
7	TCGS-1621	16.00	10.69	13.35	4.01	4.05	4.03	3.35	3.31	3.33
8	TCGS-1622	13.61	9.82	11.71	3.83	3.57	3.70	3.25	2.93	3.09
9	TCGS-1623	15.48	10.28	12.88	3.88	3.67	3.78	3.29	3.11	3.20
10	TCGS-1624	19.73	11.32	15.53	4.73	4.35	4.54	3.93	3.75	3.84
11	DHARANI	10.52	7.21	8.87	3.41	3.21	3.31	2.81	2.35	2.58
12	K6	12.37	8.05	10.21	3.57	3.31	3.44	2.96	2.63	2.80
13	NARAYANI	13.29	9.56	11.43	3.76	3.55	3.65	3.23	2.90	3.07
14	TAG-24	13.19	9.28	11.23	3.68	3.48	3.58	3.17	2.83	3.00
15	GREESHMA	12.14	8.45	10.30	3.63	3.33	3.48	2.97	2.66	2.82
16	TCGS-1511	15.95	10.45	13.20	3.96	3.86	3.91	3.33	3.18	3.26
17	TCGS-1514	13.06	8.86	10.96	3.67	3.45	3.56	3.08	2.81	2.95
18	TCGS-1517	12.60	8.60	10.60	3.65	3.43	3.54	3.04	2.75	2.89
19	TCGS-1522	12.03	7.44	9.74	3.49	3.27	3.38	2.92	2.55	2.74
20	TCGS-1528	11.67	7.33	9.50	3.46	3.23	3.35	2.83	2.49	2.66
	Mean	12.60	8.51		3.64	3.38		3.05	2.70	
		CD(P=0.05)	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**
	T	0.1534	0.05		0.0384	0.0136		0.048	0.017	
	G	0.485	0.1722	4.5	0.1214	0.0431	3.7	0.1518	0.0539	4.5
	T × G	0.686	0.2436		0.172	0.061		0.215	0.0762	

T_1: Iron Sufficient Soils; T_2: Iron Deficient Soils (Calcareous Soils); NS: Non Significant

Table 3. Evaluation of groundnut genotypes for Catalase activity (units g^{-1}(fresh wt) min^{-1}) in iron sufficient and iron deficient soil conditions

S. No	Genotypes	30 DAS			60 DAS			90 DAS		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS-1602	1.72	1.47	1.60	1.43	1.25	1.34	1.09	0.89	0.99
2	TCGS-1603	1.68	1.44	1.56	1.42	1.21	1.32	1.04	0.88	0.96
3	TCGS-1609	1.65	1.39	1.52	1.41	1.19	1.30	1.00	0.86	0.93
4	TCGS-1611	1.75	1.50	1.62	1.45	1.27	1.36	1.10	0.91	1.01
5	TCGS-1613	1.59	1.32	1.46	1.33	1.10	1.22	0.95	0.84	0.89
6	TCGS-1616	2.36	1.91	2.14	1.84	1.62	1.73	1.59	1.35	1.47
7	TCGS-1621	2.70	1.86	2.28	1.79	1.56	1.67	1.55	1.30	1.43
8	TCGS-1622	2.19	1.75	1.97	1.70	1.48	1.59	1.44	1.24	1.34
9	TCGS-1623	2.26	1.79	2.03	1.72	1.50	1.61	1.47	1.27	1.37
10	TCGS-1624	2.53	1.95	2.24	1.92	1.70	1.81	1.65	1.42	1.54
11	DHARANI	1.77	1.51	1.64	1.46	1.29	1.38	1.13	0.94	1.04
12	K6	1.87	1.59	1.73	1.55	1.35	1.45	1.22	1.03	1.13
13	NARAYANI	2.10	1.71	1.90	1.69	1.46	1.57	1.41	1.20	1.31
14	TAG-24	1.97	1.69	1.83	1.64	1.43	1.53	1.37	1.15	1.26
15	GREESHMA	1.90	1.62	1.76	1.58	1.37	1.48	1.25	1.08	1.17
16	TCGS-1511	2.50	1.83	2.17	1.76	1.53	1.64	1.50	1.28	1.39
17	TCGS-1514	1.95	1.67	1.81	1.62	1.41	1.52	1.32	1.12	1.22
18	TCGS-1517	1.93	1.63	1.78	1.61	1.39	1.50	1.29	1.10	1.19
19	TCGS-1522	1.85	1.57	1.71	1.51	1.33	1.42	1.21	1.01	1.11
20	TCGS-1528	1.81	1.55	1.68	1.48	1.31	1.40	1.15	0.96	1.06
	Mean	2.00	1.64		1.60	1.39		1.29	1.09	
		CD(P=0.05)	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**
	T	0.02	0.01		0.0137	0.0049		0.018	0.0064	
	G	0.0478	0.017	2.8	0.0434	0.0154	4	0.0568	0.0202	5.9
	T×G	0.068	0.024		NS	0.0218		NS	0.0285	

T_1: Iron Sufficient Soils; T_2: Iron Deficient Soils (Calcareous Soils); NS: Non Significant

Table 4. Evaluation of groundnut genotypes for Superoxide dismutase activity (units g^{-1}(fresh wt) min^{-1}) in iron sufficient and iron deficient soil conditions

S. No	Genotypes	30 DAS			60 DAS			90 DAS		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS-1602	0.24	0.30	0.27	0.25	0.35	0.30	0.32	0.38	0.35
2	TCGS-1603	0.20	0.28	0.24	0.24	0.34	0.29	0.30	0.37	0.34
3	TCGS-1609	0.18	0.26	0.22	0.23	0.33	0.28	0.28	0.36	0.32
4	TCGS-1611	0.23	0.31	0.27	0.27	0.36	0.31	0.33	0.39	0.36
5	TCGS-1613	0.14	0.24	0.19	0.21	0.32	0.27	0.25	0.34	0.29
6	TCGS-1616	0.47	0.51	0.49	0.52	0.54	0.53	0.54	0.55	0.55
7	TCGS-1621	0.45	0.49	0.47	0.49	0.52	0.51	0.54	0.58	0.56
8	TCGS-1622	0.40	0.43	0.41	0.41	0.48	0.44	0.48	0.53	0.51
9	TCGS-1623	0.42	0.45	0.44	0.44	0.49	0.47	0.51	0.55	0.53
10	TCGS-1624	0.49	0.54	0.52	0.54	0.56	0.55	0.57	0.59	0.58
11	DHARANI	0.25	0.32	0.29	0.29	0.38	0.34	0.35	0.40	0.38
12	K6	0.29	0.35	0.32	0.33	0.41	0.37	0.38	0.43	0.40
13	NARAYANI	0.38	0.41	0.39	0.40	0.47	0.43	0.46	0.52	0.49
15	GREESHMA	0.30	0.37	0.34	0.37	0.42	0.39	0.41	0.45	0.43
16	TCGS-1511	0.43	0.47	0.45	0.48	0.51	0.49	0.53	0.57	0.55
17	TCGS-1514	0.34	0.39	0.37	0.36	0.45	0.41	0.44	0.49	0.46
18	TCGS-1517	0.32	0.38	0.35	0.34	0.43	0.39	0.43	0.47	0.45
19	TCGS-1522	0.28	0.34	0.31	0.32	0.40	0.36	0.37	0.42	0.39
20	TCGS-1528	0.26	0.33	0.30	0.30	0.39	0.35	0.36	0.41	0.39
	Mean	0.32	0.38		0.38	0.43		0.42	0.46	
		CD(P=0.05)	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**	**CD(P=0.05)**	**SEm±**	**CV(%)**
	T	0.01	0.0019		0.0044	0.0015		0.013	0.0046	
	G	0.0165	0.0059	5.6	0.0138	0.0049	3.7	0.0411	0.0146	9.4
	T×G	0.023	0.0083		0.02	0.0069		NS	0.0207	

T_1: Iron Sufficient Soils; T_2: Iron Deficient Soils (Calcareous Soils); NS: Non Significant

the activity of oxidative stress-related enzymes like catalase, ascorbate peroxidase, and peroxidase in several plant species that is attributed to less Fe concentration in Fe- deficient leaves (M'sehli *et al.,* 2014 and Ishwar *et al.,* 2016). As catalase and peroxidase antioxidant enzymes are all heme-containing enzymes may not play essential roles in detoxifying reactive oxygen species under iron deficiency stress conditions.

The activity of superoxide dismutase increased throughout crop growth from 30 DAS to 90 DAS (Table 4). The super oxide dismutase among the genotypes showed significant differences and higher activity was recorded in TCGS-1624 and TCGS-1616 and lowest in TCGS-1613 and TCGS-1609 compared to other genotypes

SOD provides the first line of defense against the toxic effects of elevated levels of reactive oxygen species. Superoxide dismutase catalyses the dismutation of superoxide radicals to H_2O_2 and O_2, and constitutes the most important enzyme in cellular defense because its activation directly modulates the amounts of superoxide anion (O^{2-}) and H_2O_2 (Foyer & Noctor, 2000). Super oxide dismutase activity was high under iron deficiency stress conditions as it plays a key role in detoxifying reactive oxygen species under iron deficiency stress conditions. Some reports have shown that salt stress induces an increase in SOD activity, and this has frequently been correlated with salt tolerance (Sreenivasulu *et al*., 2000; Martinez *et al*., 2001; Sudhakar *et al*., 2001).

CONCLUSION

Under iron deficient soil conditions, the groundnut genotypes recorded significantly lower active iron content, peroxidase and catalase activities while higher super oxide dismutase across all three crop growth stages compared to iron sufficient soil conditions. In the groundnut genotypes TCGS-1624 and TCGS-1616 significantly higher values of active iron content, peroxidase, catalase and super oxide dismutase activities across all three crop growth stages compared to TCGS-1613 and TCGS-1609 in both iron sufficient and deficient soil conditions. This showed that the groundnut genotypes TCGS-1624 and TCGS-1616 were tolerant to iron deficiency chlorosis than TCGS-1613 and TCGS-1609.

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SCREENING OF THERMO TOLERANT FOXTAIL MILLET GENOTYPES AT SEEDLING STAGE USING THERMO INDUCTION RESPONSE TECHNIQUE (TIR)

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ABSTRACT

A novel temperature induction response (TIR) technique was standardized for foxtail millet crop. The sub lethal i.e. challenging temperatures as 38-58ºC (for 5 hours) and lethal temperatures as 59ºC (for 2 hours) was standardized. Using this standardized TIR protocol, highly thermo tolerant foxtail millet genotypes were screened from 60 foxtail millet germplasm. Among the genotypes, Prasad, SiA 3580, SiA 3604, SiA 3618, SiA 3623, SiA 3625 showed high thermo tolerance in terms of 70-100 per cent seedlings survival and 2-15% reduction in root and 7-18% reduction in shoot growth. These genotypes have intrinsic heat tolerance and they can be explored as donar source for developing high temperature tolerant foxtail millet genotypes.

KEYWORDS: TIR, foxtail millet, heat tolerance

INTRODUCTION

Foxtail millet (*Setaria italica* L.) is one of the oldest cultivated small millets both for food and fodder. It ranks second in the total world production of small millets and it continues to have an important place in world agriculture providing food for millions of people in arid and semiarid regions. It is native to China, India and Pakistan with the rainfall ranging from 150-700 mm and regarded as an elite drought tolerant crop. In India, it is cultivated in Andhra Pradesh, Karnataka, Maharastra, Tamilnadu, Odissa, Rajasthan and Madhya Pradesh for staple food as well as fodder. In India, foxtail millet is cultivated in 98,000 ha. area with a production of 56 t ha^{-1} and productivity of 565 kg ha^{-1} and in Andhra Pradesh, it is cultivated in an area of 23,005 hectares with a production of 28,348 tonnes and productivity of 1232 kg ha^{-1} (Anonymous, 2015).

Heat stress due to high ambient temperatures is a serious threat to crop production worldwide (Hall, 2001). High temperature stress affects all growth stages of crops and ultimately affects the yields. This is further aggravated by other environmental stresses like intermittent drought and high light. Management options are few, hence developing intrinsically tolerant lines is essential to combat the situation. With this background, foxtail millet genotypes were screened for high temperature tolerance using temperature induction response (TIR) technique. This approach is based on the fact that temperature stress develops gradually from sub lethal to lethal levels. An array of response events were expressed during sub lethal temperatures and gave cellular protection at lethal temperatures (Abdullah *et al.* 2001).

MATERIAL AND METHODS

Present investigation was conducted at Institute of Frontier Technology, Acharya N. G. Ranga Agricultural University. Tirupati, Andhra Pradesh with 60 foxtail millet genotypes obtained from Agricultural Research Station, Nandyal, Andhra Pradesh (Table 1).

Identification of lethal temperature treatment

To assess the challenging temperatures for 100 per cent mortality, 24 hour old foxtail millet seedlings were exposed to different lethal temperatures (55°C, 56°C, 57°C, 58°C and 59°C) for the same duration (2 hours) without prior induction. Thus, exposed seedlings were allowed to recover at 30^0C and 60 per cent relative humidity for 48 hours. At the end of recovery period the temperature at which 90% mortality of the seedlings occurred was taken as the challenging temperature in order to assess the genetic variability for seedling survival. Per cent mortality of foxtail millet genotypes after recovery was recorded (Table 2). The lethal temperature of 59°C for 2 hours was considered in this context, as maximum mortality (100%) of seedlings.

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Identification of sub lethal (induction) temperature

During the induction treatment, the seedlings were exposed to a gradual increase in temperature for a specific period. The temperature regimes and duration varies from crop to crop and need to be standardized. The germinated foxtail millet seedlings (24 hour old seedlings) were subjected to gradually increasing temperatures for a period of five hours. After this induction treatment, seedlings were exposed to lethal temperature *i.e.,* 59^{0}C for two hours and then transferred to the normal temperature for recovery. The temperature regimes and durations varied to arrive at optimum induction protocol (Table 3). The optimum sub lethal temperatures were arrived based on the per cent survival of seedlings. The sub lethal treatment which recovered least per cent seedlings survival reduction was considered as optimum range of temperatures *i.e.,* 38°C-58°C.

Thermo Induction Response (TIR)

Foxtail millet seeds were surface sterilized by treating with 2 per cent carbendazim solution for 30 minutes and washed with the distilled water for 4-5 times and kept for germination at 30°C and 60 per cent relative humidity in the incubator. After 24 hours, uniform seedlings were selected in each genotype and sown in aluminium trays (50 mm) filled with soil. These trays with seedlings were subjected to sub lethal temperatures (gradual temperatures increasing from 38°C-58°C for five hours in the environmental chamber (WGC-450 Programmable Plant Growth Chamber). Later these seedlings were exposed to lethal temperatures (59°C) for 2 hours (induced). Another set of seedlings were directly exposed to lethal temperatures (non induced).

Induced and non induced foxtail seedlings were allowed to recover at 30°C and 60 per cent relative humidity for 24 hours. The following parameters were recorded from the seedlings.

a) Per cent survival of seedlings =

$$\frac{\text{No. of seedlings survived at the end of recovery}}{\text{Total number of seedlings sown in the tray}} \times 100$$

b) Per cent reduction in root growth =

$$\frac{\text{Actual root growth of control seedlings} - \text{Actual root growth of treated seedlings}}{\text{Actual root growth of control seedlings}} \times 100$$

c) Per cent reduction in shoot growth

$$\frac{\text{Actual shoot growth of control seedlings} - \text{Actual shoot growth of treated seedlings}}{\text{Actual shoot growth of control seedlings}} \times 100$$

A lethal temperature of 59^{o}C for 2 hours and induction treatment from 38-58^{o}C for five hours was standardized using TIR (Thermo Induction Response) (Fig. 1) and considered as best lethal and induction temperatures for Phenotyping of foxtail millet seedlings for intrinsic heat tolerance at cellular level. (Table 2 and Table 3).

RESULTS AND DISCUSSION

The experimental data was recorded and the genotypes which showed contrast values for survival of seedlings, reduction in root and shoot growth were presented in the Table 4. Among the 60 genotypes screened, Prasad, SiA 3580, SiA 3604, SiA 3618, SiA 3623, SiA 3625 showed the highest thermo tolerance in terms of 70-100 per cent seedlings survival and only 2-15 reduction in root and 7-18 reduction in shoot growth. These varieties here shown the ability to survive even when they were exposed to lethal temperatures. In spite of exposing to 59^{o}C, germination and seedling growth were not affected in the genotypes, Prasad, SiA 3580, SiA 3618 and SiA 3623 probably due to acquired thermo tolerance. In the genotypes *viz.,* SiA 3555, SiA 3563, SiA 3569 and SiA 3572 the seedling survival, shoot and root growth were completely affected despite of the recovery conditions maintained after exposing to sub lethal to lethal temperature. The technique of exposing young seedlings to sub lethal and lethal temperatures has been validated in many crop species by several scientists in different crop species, Sudhakar *et al.* (2012) and Renukha *et al.* (2013) in rice, Senthil kumar *et al.* (2003) in sunflower, Ehab Abou Kheir *et al.* (2012) in cotton, Gangappa *et al.* (2006), in groundnut, Venkatachalayya *et al.* (2001) in pea and they concluded that TIR technique is one of the best screening techniques to screen the genotypes for thermo-tolerance.

CONCLUSION

The present study releaved that the TIR technique be used in foxtail millet crop for identifying thermo tolerant genotypes. In the present study, six genotypes *viz.*, Prasad, SiA 3580, SiA 3618, SiA 3604, SiA 3625

Table 1. Details of the respective 60 foxtail millet genotypes

S. No.	Genotype	S. No.	Genotype
1	Suryanandi (Check)	31	Sri Lakshmi (Check)
2	SiA 3539	32	SiA 3589
3	SiA 3542	33	SiA 3591
4	SiA 3543	34	SiA 3595
5	SiA 3545	35	SiA 3596
6	SiA 3546	36	SiA-3598
7	SiA 3550	37	SiA 3600
8	SiA 3551	38	SiA 3604
9	SiA 3554	39	SiA 3605
10	SiA 3555	40	SiA 3607
11	Narasimharaya (Check)	41	Krishnadevaraya (Check)
12	SiA 3558	42	SiA 3608
13	SiA 3559	43	SiA 3610
14	SiA 3560	44	SiA 3611
15	SiA 3562	45	SiA 3613
16	SiA 3563	46	SiA 3615
17	SiA 3569	47	SiA 3618
18	SiA 3570	48	SiA 3619
19	SiA 3572	49	SiA 3622
20	SiA-3574	50	SiA 3623
21	Prasad (Check)	51	SiA 3085 (Check)
22	SiA 3575	52	SiA 3625
23	SiA 3578	53	SiA 3626
24	SiA 3580	54	SiA 3628
25	SiA 3581	55	SiA 3631
26	SiA 3582	56	SiA 3632
27	SiA 3583	57	SiA 3634
28	SiA 3584	58	SiA 3636
29	SiA 3585	59	SiA 3637
30	SiA 3586	60	SiA 3156 (Check)

Table 2. Per cent mortality of foxtail millet seedlings at different lethal temperatures

S. No.	Temperature °C	Per cent mortality of foxtail seedlings after recovery		
		Duration of temperature		
		1 hour	2 hour	3 hour
1	55	0	0	7
2	56	0	21	33
3	57	0	50	59
4	58	51	81	86
5	59	62	100	100

Table 3. Per cent survival of foxtail seedlings at different induction (sub lethal) temperature range

S. No.	Temperature Range (Induction treatment for 5 hrs)°C	Per cent survival of seedling
1	34-53	80
2	34-55	86
3	36-56	86
4	36-57	88
5	38-58	95
6	38-59	84

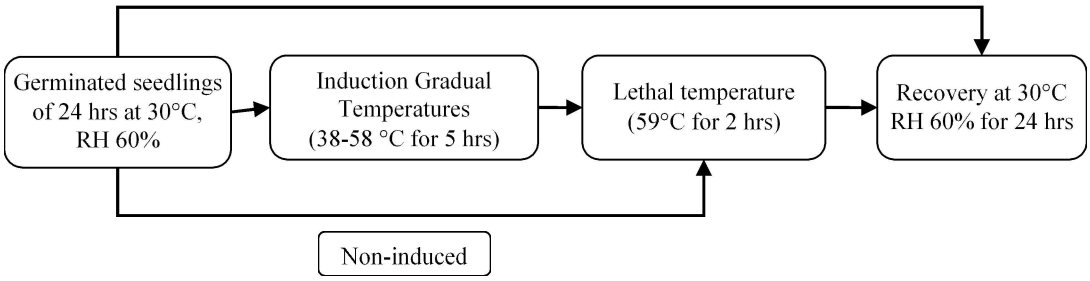

Fig. 1. Protocol of the technique: Temperature Induction Response (TIR)

Table 4. List of promising thermo tolerant and sensitive foxtail genotypes identified through TIR technique

Tolerance range	Genotype	Per cent reduction in root growth (%)	Per cent reduction in shoot growth (%)	Per cent survival of seedlings (%)
Highly Tolerant Germplasm Lines	Prasad	3	18	100
	SiA 3580	8	7	95
	SiA 3604	15	11	95
	SiA 3618	2	13	95
	SiA 3623	2	17	70
	SiA 3625	9	16	100
Highly Sensitive Germplasm lines	SiA 3555	72	69	60
	SiA 3563	68	67	60
	SiA 3569	64	70	55
	SiA 3572	62	58	55

and SiA 3623 showed high level of thermo tolerance. These genotypes can be used as potent donar sources in breeding programmes aimed for development of genotypes against high temperatures.

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STATISTICAL ANALYSIS AND FORECASTING OF GROUNDNUT LEAFHOPPER BASED ON CLIMATE FACTORS IN CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

This paper presents the groundnut leafhopper incidence and the influence of climatic factors in groundnut growing areas of Chittoor district of Andhra Pradesh. The data analysis on leafhopper incidence and its correlation with the climate factors in standard weeks of groundnut growing seasons from 2007 to 2016 revealed that the rainfall distribution varied greatly within groundnut growing seasons over years. The average minimum temperatures ranged from 12.8°C – 32.5°C, average maximum temperatures ranged from 25.7°C – 41.9°C, morning relative humidity ranged from 36.8 – 95% and evening relative humidity ranged from 21.5 – 91.5%. The results revealed that the days with RH > 78 per cent, temperature ranging from 13°C – 42°C and rainfall ranging from 0.00 to 297 mm are most critical factors for incidence of leafhopper. Correlation coefficients were computed to ascertain the pattern of relationship between leafhopper and climate factors over years (2007-2016). The results revealed that there was a positive relationship between the leafhopper incidence and rainfall, evening relative humidity and sunshine hours. The MLR models for within year and between years found to be useful in the prediction of leafhopper incidence. The logistic models were found to be useful in the prediction of probabilities for occurrence and non-occurrence of leafhopper incidence of groundnut. The markov chain models revealed that there was significant change in occurrence of leafhopper in consecutive days.

KEYWORDS: Leafhopper, climate factors, logistic regression, MLR models, Markov chain models.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an annual legume crop belonging to the family Fabaceae and is commonly known as peanut. It forms the world' largest source of edible oil and ranks 13th among the food crops and 4th among the most important oilseed crops of the world. The major groundnut growing countries in the world are India, China, Nigeria and Myanmar, which occupies an area of 25.41 M ha, producing 41.20 MT with an average productivity of 1620 kg ha^{-1} (USDA, 2013-14). In India, groundnut occupies an area of 5.51 M ha producing 9.714 MT with an average productivity of 1764 kg ha^{-1} (www.indiastat.com, 2013-14). Gujarat and Andhra Pradesh are the major groundnut growing states in India. In Andhra Pradesh, the crop is grown in an area of 1.386 M ha producing 1.236 MT with an average productivity of 949 kg ha^{-1} (Anonymous, 2014).

Groundnut oil is considered as staple and nutritive food as it contains just the right proportion of Oleic and Linoleic acids (Mathur and Khan, 1997). More than 100 species of insect and mites are known to attack groundnut (Nandagopal, 1992). Among the various insect pests attacking this crop, jassid commonly known as leafhopper, causes extensive damage. Leafhoppers are the major pest of importance on groundnut crop specially when raised under summer conditions (David and Ramamurthy, 2011). Leafhoppers suck the sap from the leaves (prefers first three terminal leaves) and petioles producing 'V' shaped yellowing at the tip, known as hopper burn (Khan and Hussain, 1965). The present work was carried out by keeping in mind the importance pet forecasting and role of correlations between incidence of insect pest species and weather parameters. The information on correlation between insect pest incidence and weather parameters will be of great help in formulating better Integrated Pest Management (IPM) practices that are area specific.

MATERIAL AND METHODS

The secondary data pertaining to leafhopper incidence was collected from the Regional agricultural research station (RARS), Tirupati along with weather data

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from Meteorological observatory available at RARS, Tirupati. The data was collected from the period ranging from 2007 to 2016. The data was analysed by using the various statistical techniques *viz.,* Simple statistics, Correlation, Multiple Linear Regression (MLR), Logistic Regression and Markov chain models with the help of SAS 9.3 software (SAS, 2016).

RESULTS AND DISCUSSION

The data analysed based on average climatic factors from 2007 to 2016 from groundnut growing seasons revealed that the average rainfall distribution varied greatly within groundnut growing seasons over years (0.0mm to 296.4mm). The average minimum temperatures ranged from 12.8^{0}C to 32.5^{0}C; maximum temperature ranged from 25.7^{0}C to 41.9^{0}C; morning relative humidity ranged from 36.8 to 95% and evening relative humidity ranged from 21.5 to 91.5%.

The data analysed on leafhopper incidence during the year 2012, revealed that the morning relative humidity and sunshine hours showed significant negative association, maximum temperature, minimum temperature and rainfall exhibited significant positive association and evening relative humidity and wind velocity exhibited non-significant positive association with the leafhopper incidence. The multiple linear regression model revealed that the influence of weather variables on leafhopper incidence was to the extent of 52 per cent ($R^2 = 0.52$).

During the year 2013, the results showed that the wind velocity exhibited significant negative association, maximum temperature and sunshine hours exhibited non-significant negative association, evening relative humidity and rainfall exhibited significant positive association and minimum temperature and morning relative humidity exhibited non-significant positive association with leafhopper incidence. The multiple linear regression model revealed that the influence of weather variables on leafhopper incidence was to the extent of 25 per cent ($R^2 = 0.25$).

During the year 2014, the results revealed that the maximum temperature, sunshine hours and wind velocity showed significant negative association, minimum temperature exhibited non-significant negative association, morning relative humidity, evening relative humidity and rainfall exhibited significant positive association with leafhopper incidence. The multiple linear regression model revealed that the influence of weather variables on leafhopper was to the extent of 60 per cent ($R^2 = 0.60$).

Table 1. Descriptive statistics for leafhopper during the years 2007 to 2016

Simple Statistics				
Variable	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Leafhopper	36.44	25.71	10.14	168.57
Max_Tem	33.24	3.14	25.70	41.90
Min_Tem	22.51	3.49	12.80	32.50
MRH	77.62	10.30	36.80	95.00
ERH	48.75	12.46	21.50	91.50
RF	23.26	40.92	0.00	296.40
SSH	5.49	2.26	0.30	13.60
WV	6.28	2.70	1.99	19.30

During the year 2015, the results revealed that the sunshine hours showed significant negative association, maximum temperature and wind velocity showed non-significant negative association, evening relative humidity exhibited significant positive association and minimum temperature, morning relative humidity and rainfall exhibited non-significant positive association. The multiple linear regression model revealed that the influence of weather variables on leafhopper was to the extent of 26 per cent ($R^2 = 0.26$).

During the year 2016, the analysis revealed that the morning, evening relative humidity, and sunshine hours showed non-significant negative association, maximum temperature, minimum temperature, rainfall and wind velocity showed non-significant positive association with leafhopper incidence. The multiple linear regression model revealed that the influence of weather variables on leafhopper was to the extent of 24 per cent ($R^2 = 0.24$).

Overall from the year 2007-16, the data analysis revealed that the minimum temperature and morning relative humidity showed non-significant negative association , wind velocity showed significant negative association and maximum temperature exhibited non-significant positive association and evening relative humidity rainfall and sunshine hours exhibited significant positive association with leafhopper incidence. The multiple linear regression model revealed that the influence of weather variables on leafhopper to the extent of 64 per cent ($R^2 = 0.54$).

Table 2. Correlation coefficients of different climate factors with leafhopper population

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0							
Year	**Max_Tem**	**Min_Tem**	**MRH**	**ERH**	**RF**	**SSH**	**WV**
2012	0.27759 (**0.0529**)	0.59837 (**0.0001**)	-0.52841 (**0.0005**)	0.19610 (0.2252)	0.41618 (**0.0076**)	-0.49717 (**0.0011**)	0.17105 (0.2913)
2013	-0.16063 (0.2976)	0.11859 (0.4433)	0.25210 (0.0988)	0.36754 (**0.0141**)	0.22035 (**0.0150**)	-0.15742 (0.3075)	-0.2692 (**0.0772**)
2014	-0.32856 (**0.0174**)	-0.10539 (0.4571)	0.31824 (**0.0215**)	0.64950 (**0.0001**)	0.29577 (**0.0333**)	-0.31158 (**0.0245**)	-0.3735 (**0.0064**)
2015	-0.13162 (0.3523)	0.17444 (0.5999)	0.19241 (0.5147)	0.40543 (**0.0029**)	0.20080 (0.1535)	-0.27128 (**0.0517**)	-0.1171 (0.4080)
2016	0.11657 (0.9072)	0.15119 (0.2847)	-0.15759 (0.2645)	-0.1574 (0.6861)	0.10673 (0.4514)	-0.23379 (0.0953)	0.11432 (0.9197)
2007-16	0.16124 (0.2246)	-0.17274 (0.1490)	-0.21470 (0.7709)	0.22053 (**0.0001**)	0.32796 (**0.0109**)	0.23521 (**0.0071**)	-0.3306 (**0.0001**)

The values in parenthesis are probabilities.
The highlighted values are significant probabilities with respect 5 % / 1 % LOS

Table 3. Multiple regression functions for the prediction of leafhopper population

Year	Pest	Equation	R^2
2012	Leafhopper	-119.53 + (17.47) X_1 + (0.15)X_2 + (-5.34) X_3 + (4.56) X_4 + (0.30) X_5 + (6.87) X_6 + (-1.05) X_7 + (-12.46) X_8	0.52
2013	Leafhopper	193.25 + (-8.23) X_1 + (12.54) X_2 + (-1.80) X_3 + (3.87) X_4 + (-1.07) X_5 + (38.61) X_6 + (4.61) X_7 + (-15.18) X_8	0.25
2014	Leafhopper	-218.78 + (1.49) X_1 + (4.29) X_2 + (0.17) X_3 + (2.49) X_4 + (0.45) X_5 + (-5.44) X_6 + (3.58) X_7 + (-4.65) X_8	0.60
2015	Leafhopper	-26.98 + (0.66) X_1 + (0.57) X_2 + (-0.22) X_3 + (0.91) X_4 + (-0.15) X_5 + (4.43) X_6 + (0.24) X_7 + (-0.58) X_8	0.26
2016	Leafhopper	154.09 + (-2.33) X_1 + (0.78) X_2 + (-0.18) X_3 + (-0.77) X_4 + (0.08) X_5 + (-0.36) X_6 + (-1.41) X_7 + (-0.34) X_8	0.24
2007-16	Leafhopper	461.13 + (-8.98) X_1 + (9.89) X_2 + (-2.93) X_3 + (1.39) X_4 + (-0.27) X_5 + (7.02) X_6 + (-3.19) X_7 + (-16.50) X_8	0.54

Table 4. Logistic regression function of climate factors with leafhopper

Pest	MSW	Equation	R^2
Leafhopper	46	-1056.6 + (25.38) X_1 + (3.71) X_2 + (3.66) X_3 + (-2.04) X_4 + (0.52) X_5 + (-1.47) X_6 + (10.47) X_7	0.56
Leafhopper	47	110.8 + (-2.06) X_1 + (4.01) X_2 + (0.04) X_3 + (-1.43) X_4 + (-0.04) X_5 + (-6.97) X_6 + (0.24) X_7	0.61
Leafhopper	48	254.6 + (-4.89) X_1 + (4.05) X_2 + (0.54) X_3 + (-1.78) X_4 + (0.09) X_5 + (-2.72) X_6 + (-3.22) X_7	0.50
Leafhopper	49	-526.3 + (15.05) X_1 + (5.80) X_2 + (-0.28) X_3 + (1.41) X_4 + (-0.12) X_5 + (-1.71) X_6 + (-12.84) X_7	0.65

Table 5. Table representing the frequencies of transitions for leafhopper from 2007-16

	Period I (2007-11)		Period II (2012-16)	
A=	0	1	0	1
0	26	6	6	4
1	7	105	3	132

Table 6. T.P.M'S of leafhopper in different periods

	Period I (2007-11)		Period II (2012-16)	
R=	0	1	0	1
0	0.8125	0.1875	0.6129	0.4122
1	0.0625	0.9375	0.0294	0.9706

The fitted logistic regression models were found to be useful in predicting the occurrence/ non-occurrence of leafhopper incidence of various standard weeks. The results based on Markov chain model revealed that, the limiting behaviour of the TPMs was obtained for leafhopper for two different periods, the period II (2012-16) limiting behaviour of occurrence of pest for two consecutive days is very high (0.9315) than period I (2007-11) (0.75).

Table 7. Higher order transition probabilities of leafhopper for the year 2007-16

	Period I (2007-11)		Period II (2012-16)	
P =	0	1	0	1
0	0.8125	0.1875	0.6129	0.4122
1	0.0625	0.9375	0.0294	0.9706
$P^{(2)}$ =	0	1	0	1
0	0.6718	0.3281	0.3717	0.6282
1	0.1093	0.8906	0.0461	0.9538
$P^{(4)}$ =	0	1	0	1
0	0.4873	0.5126	0.1672	0.8327
1	0.1708	0.8291	0.0612	0.9387
$R^{(8)}$ =	0	1	0	1
0	0.3250	0.6749	0.0789	0.9210
1	0.2249	0.7750	0.0676	0.9323
$R^{(16)}$ =	0	1	0	1
0	0.2575	0.7424	0.0685	0.9314
1	0.2474	0.7525	0.0684	0.9315
$R^{(16)}$ =	0	1	0	1
0	0.25	0.75	0.0684	0.9315
1	0.25	0.75	0.0684	0.9315

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LABORATORY EVALUATION OF *Bacillus thuringiensis* (Berliner) NATIVE TO FOREST ECOSYSTEM AGAINST *Spodoptea litura* (Fabricius)

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ABSTRACT

A total of 61 *Bacillus thuringiensis* strains were collected from 264 soil samples representing different forest ecosystem in Southern zone of Andhra Pradesh in Chittoor, Kadapa and Nellore districts during 2014-2016. These strains were tested for their efficacy against third instar larvae of *Spodoptera litura* in laboratory bioassay studies. A series of 0.00 to 53.33; 0.00 to 20.00; 0.00 to 30.00; 0.00 to 30.00 and 0.00 to 23.33 per cent larval mortality was observed at 72, 96, 120, 144 and 168 hours after treatment, respectively. A cumulative mortality of 0 to 100 per cent was observed among the 61 strains collected from forest ecosystem. The *Bt* strain F493 recorded highest mortality of 100 per cent, followed by F468 (86.67%) which were comparable with standard strain HD-1 for their efficacy. The other strains F287 (76.67%), F504 (76.67%) were proved next best to F493, HD-1 and F468 for their efficacy which were statistically on par with each other.

KEYWORDS: *Bacillus thuringiensis*, bioassay studies, forest soils, *Spodoptera litura*.

INTRODUCTION

Spodoptera litura (Fabricius) is a serious insect pest on groundnut during *rabi* in groundnut growing regions of Andhra Pradesh particularly in Chittoor, Kadapa, Nellore and Anantapur districts. Application of synthetic insecticides is one of the major strategies used by the farmers for managing this pest. The farmers of Chittoor district apply around 4-5 rounds of insecticides including combination insecticides for managing *S. litura*. Brooke and Hines (1999) reported that, 40 per cent of the broad spectrum chemical insecticides have been targeted for the control of lepidopteran pests.

Microbial pesticides are considered as an important component of IPM, among which *Bt* based biopesticides occupies the pivotal position. *Bt* is a Gram-positive bacterium, stands out representing approximately 95 per cent of microorganisms used in biological control of agricultural pests in different countries, which accounts for 1.3 per cent of total pesticides (Ramanujam *et al*., 2014). Though commercial *Bt* strains have been used since ages for managing the lepidopteran pests, there is a need to isolate and test the efficacy of locally available *Bt* strains that can fit into local agro ecosystem.

MATERIAL AND METHODS

The studies were carried out at Regional Agricultural Research Station, Tirupati during 2014-15 and 2015-16. A total of 264 soil samples were collected from forest ecosystem in Southern zone of Andhra Pradesh representing three districts *viz.,* Chittoor, Kadapa and Nellore. Out of 264 soil samples, 61 *B.thuringiensis* strains were isolated and these strains along with standard strain HD-1 were used to determine their activity against *S. litura* in laboratory bioassay. All the 61 strains along with standard strain was inoculated on Luria Bertani agar media and incubated overnight at 37^0C. One loop of overnight cultures was inoculated in Luria broth and kept for sporulation under shaking condition at 28^0 C for 24h. *S. litura* culture was reared till III instar for conducting bioassay studies. The bioassay experiment had 63 treatments with three replications.

Bioassay was followed by leaf dip bioassay method developed by Shelton *et al.* (1993). Groundnut compound leaf containing four leaflets was dipped for 10 minutes into *Bt* culture broth (5×10^8 CFU 1 mL^{-1}) containing 0.2 per cent Triton X-100, then kept leaf for air drying till leaf surface free from moisture. After drying, the petiole of leaf was swabbed with wet cotton to maintain leaf

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succulence and turgidity. Two compound leaves were used for one replication, which was placed in a Petri plate of 9 cm diameter. Ten larvae were released per one replication. HD-1 served as a reference strain. The leaf dipped in distilled water served as control. The larval mortality was assessed after 72h at regular intervals. The data subjected to ANOVA in one way analysis using GENSTAT.

RESULTS AND DISCUSSIONS

A total of 61 strains which were native to forest ecosystem of southern zone of Andhra Pradesh were assessed for their efficacy against third instar larvae of *S. litura*. A series of 0.00 to 53.33; 0.00 to 20.00; 0.00 to 30.00; 0.00 to 30.00 and 0.00 to 23.33 per cent larval mortality was observed at 72, 96, 120, 144 and 168 hours after bioassay. A cumulative mortality of 0.00 to 100 per cent was observed in different strains after 168 hours of bioassay.

Among the 61 strains, F468, with larval mortality of 53.33 per cent was found as effective as standard check HD-1, which was superior over all other strains at 72 hours after bioassay. Next best strains, in the efficacy order were F437 (43.33%), F504 (40.00%), F493 (40.00%), F487 (40.00%) and these strains were statistically on par with each other in their efficacy. The larval mortality after 96 hours after bioassay was 36.67 per cent in F493, followed by F399 (30.00%) which were comparable with standard check HD-1 (36.67%). The other strains, F261, F323, F435 recorded a larval mortality of 20.00 per cent, followed by F468 (16.67%), F500 (13.33%), F462 (13.33%), F493 (13.33%), F399 (13.33%), F347 (13.33%) which were statistically on par with each other at 120h. F262 (30.00%), F268 (30.00%) and F307 (23.33%) recorded higher mortality (on par with each other) at 144h and 168h after bioassay F440 recorded recorded 26.67 per cent larval mortality followed by F254 (23.33%), F258 (20.00%), F281 (23.33%), F287 (20.00%), F307 (20.00%), F486 (20.00%) and F491 (23.33%) which were statistically on par with each other.

A cumulative mortality of 0 to 100 per cent was observed among the 61 strains collected from different forest ecosystem. *Bt* strain F493 recorded a higher mortality of 100 per cent, followed by F468 (86.67%) which were comparable with standard strain HD-1 for their efficacy. The other strains F287 (76.67%), F504 (76.67%) were also next best to F493, HD-1 and F468 for their efficacy which were statistically on par with each other (Table.1).

The present results of 100 per cent larval mortality of *S. litura* with locally available *Bt* strains was in accordance with that of Nariman *et al.* (2009) who reported a higher mortality of 100 per cent and 90 per cent of second instar *Spodoptera littoralis* with two *Bt* strains Ts-5 and As-3 collected from seven governorates of Egypt. Meadows (1993) also reported elevated levels of insecticidal activity against *Galleria mellonella* with *B. thuringiensis* strains isolated from cultivated environments, which are preferred by lepidopteran insects.

Further, Meihiar *et al*. (2015) reported that, forest, beach and cultivated soils had more *B. thuringiensis* strains than uncultivated and interior arid soils. The frequency of *B. thuringiensis* was partially dependant on organic matter and pH content of the soil. A total of 65 per cent of the strains were found to be toxic to *Galleria mellonella.* The most toxic isolate of *B. thuringiensis* was obtained from cultivated area and produced bipyramidal, cuboidal and rectangular inclusions.

In present study, only four strains out of 61 strains recorded mortality in the range of 76-100 per cent against larvae of *S. litura* (Table 2). Similarly, Merdan *et al.,* (2010) reported that, among ten *B. thuringiensis* strains they tested two were potent against *S. littoralis* (Boisduval), another two strains against *Helicoverpa armigera* (Hubner) and six strains were potent against *Pectinophora gossypiella* (Saunders). Contrary to this, Valicente and Barreto (2003) reported a higher frequency of 62 per cent of *Bt* strains recorded mortality between 81 to 100 per cent.

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Table 1. Bioassay of *B. thuringiensis* strains collected from Forest ecosystem against third instar *S. litura* larvae under laboratory conditions

S. No.	Isolate	Per cent mortality					
		72 h	96 h	120 h	144 h	168 h	Cumulative
1	F252	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}
2	F254	0.00 (0.00)^{a}	3.33 (6.15)^{abcd}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	23.33 (28.78)^{ef}	26.67 (30.79)$^{d-i}$
3	F256	0.00 (0.00)^{a}	0.00 (0.00)^{a}	3.33 (6.15)^{ab}	10.00 (18.44)$^{b-fg}$	3.33 (6.14)^{ab}	16.67 (23.36)^{def}
4	F258	0.00 (0.00)^{a}	10.00 (18.44)^{efg}	0.00 (0.00)^{a}	3.33 (6.15)^{ab}	20.00 (26.57)^{def}	33.33 (35.22)$^{e-j}$
5	F261	0.00 (0.00)^{a}	0.00 (0.00)^{a}	20.00 (26.07)^{d}	10.00 (15.00)$^{b-f}$	13.33 (17.71)$^{b-f}$	43.33 (41.07)^{ghijk}
6	F262	10.00 (15.00)^{bcd}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	30.00 (33.00)^{h}	6.67 (12.29)^{abcd}	46.67 (43.08)^{hijk}
7	F263	10.00 (18.43)^{cde}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.00 (18.43)^{de}
8	F268	0.00 (0.00)^{a}	16.67 (23.86)^{efghi}	0.00 (0.00)^{a}	30.00 (33.00)^{h}	13.33 (21.14)$^{b-f}$	60.00 (50.85)^{jklm}
9	F277	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}
10	F281	20.00 (26.07)^{efghi}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	23.33 (28.78)^{ef}	43.33 (41.15)^{ghijk}
11	F284	20.00 (26.07)^{efghi}	6.67 (12.29)^{ade}	0.00 (0.00)^{a}	10.00 (15.00)$^{b-f}$	6.67 (8.86)^{abc}	43.33 (40.78)^{fghijk}
12	F287	20.00 (26.07)^{efghi}	26.67 (30.79)^{hijkl}	0.00 (0.00)^{a}	10.00 (18.44)$^{b-fg}$	20.00 (26.57)^{def}	76.67 (61.22)^{lmn}
13	F297	10.00 (18.43)^{cde}	23.33 (28.78)^{ghijkl}	0.00 (0.00)^{a}	10.00 (15.00)$^{b-f}$	6.67 (12.29)^{abcd}	50.00 (45.00)^{ijkl}
14	F307	0.00 (0.00)^{a}	10.00 (18.44)^{efg}	0.00 (0.00)^{a}	23.33 (28.78)^{gh}	20.00 (26.07)^{def}	53.33 (47.01)^{ijkl}
15	F309	3.33 (6.14)^{ab}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	16.67 (23.86)^{efgh}	6.67 (12.29)^{abcd}	26.67 (31.00)$^{d-i}$
16	F316	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	16.67 (23.86)^{cdef}	16.67 (23.86)^{defg}
17	F321	33.33 (34.93)^{ijklm}	6.67 (12.29)^{abde}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.00 (18.43)$^{b-f}$	50.00 (45.08)^{ijkl}
18	F323	13.33 (21.14)^{cdef}	3.33 (6.15)^{abcd}	20.00 (21.15)^{cd}	10.00 (15.00)$^{b-f}$	10.00 (18.43)$^{b-f}$	56.67 (49.22)^{jkl}
19	F328	6.67 (12.29)^{bc}	16.67 (19.22)^{efgh}	6.67 (12.29)^{bc}	10.00 (11.07)$^{a-e}$	10.00 (11.07)^{abcd}	50.00 (45.00)^{ijkl}
20	F339	3.33 (6.14)^{ab}	10.00 (15.00)^{def}	13.33 (17.71)^{cd}	6.67 (8.86)^{abcd}	16.67 (23.86)^{cdef}	50.00 (45.00)^{ijkl}
21	F347	10.00 (18.43)^{cde}	13.33 (21.15)^{efgh}	13.33 (17.71)^{cd}	0.00 (0.00)^{a}	13.33 (17.71)$^{b-f}$	50.00 (44.71)^{ijkl}
22	F361	10.00 (18.43)^{cde}	20.00 (26.07)^{fghij}	10.00 (15.00)^{bcd}	3.33 (6.15)^{ab}	10.00 (15.00)$^{a-e}$	53.33 (47.22)^{ijkl}

Cont...

Table 1. Cont...

S. No.	Isolate	Per cent mortality					
		72 h	96 h	120 h	144 h	168 h	Cumulative
23	F396	13.33 (21.14)^{cdef}	10.00 (15.00)^{def}	10.00 (15.00)^{bcd}	10.00 (15.00)$^{b-f}$	6.67 (12.29)^{abcd}	50.00 (45.00)^{ijkl}
24	F399	13.33 (21.14)^{cdef}	30.00 (33.00)^{ijkl}	13.33 (21.15)^{cd}	0.00 (0.00)^{a}	10.00 (15.00)$^{a-e}$	66.67 (54.99)^{klm}
25	F429	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.00 (18.44)^{cd}	6.67 (12.29)$^{a-e}$	0.00 (0.00)^{a}	16.67 (23.86)^{defg}
26	F430	0.00 (0.00)^{a}	0.00 (0.00)^{a}	6.67 (12.29)^{bc}	0.00 (0.00)^{a}	3.33 (6.14)^{ab}	10.00 (15.00)^{abd}
27	F432	16.67 (23.86)^{defg}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	16.67 (23.86)^{cdef}	33.33 (35.01)$^{e-j}$
28	F433	30.00 (33.00)^{ghijkl}	13.33 (21.15)^{efgh}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	6.67 (12.29) ^{abcd}	50.00 (45.08)^{ijkl}
29	F434	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.00 (18.43)$^{b-f}$	10.00 (18.43)^{de}
30	F435	20.00 (26.07)^{efghi}	0.00 (0.00)^{ab}	20.00 (26.07)^{d}	0.00 (0.00)^{a}	10.00 (18.43)$^{b-f}$	50.00 (45.00)^{ijkl}
31	F436	30.00 (33.00)^{ghijkl}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	13.33 (21.14)$^{b-f}$	43.33 (41.15)^{ghijk}
32	F437	43.33 (41.15)^{lmn}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	16.67 (23.86)^{cdef}	60.00 (50.85)^{jklm}
33	F438	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}
34	F440	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	26.67 (31.00)^{f}	26.67 (31.00)$^{d-i}$
35	F441	0.00 (0.00)^{a}	10.00 (15.00)^{def}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.00 (15.00)^{abcd}
36	F443	26.67 (31.00)^{fghijkl}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	26.67 (31.00)$^{d-i}$
37	F444	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	16.67 (19.93)^{bdefg}	10.00 (18.43)$^{b-f}$	26.67 (30.29)$^{d-i}$
38	F445	20.00 (26.07)^{efghi}	3.33 (6.15)^{abcd}	3.33 (6.15)^{ab}	0.00 (0.00)^{a}	6.67 (8.86)^{abc}	33.33 (35.01)$^{e-j}$
39	F447	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	13.33 (21.15)^{defgh}	0.00 (0.00)^{a}	13.33 (21.14)^{de}
40	F455	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	15.00 (15.00)$^{a-e}$	10.00 (15.00)^{ad}
41	F457	13.33 (21.14)^{cdef}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	3.33 (6.14)^{ab}	16.67 (23.86)^{defg}
42	F459	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}
43	F462	33.33 (34.93)$^{h-m}$	16.67 (23.86)^{efghi}	13.33 (21.15)^{cd}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	63.33 (53.07)^{klm}

Cont...

Table 1. Cont...

S. No.	Isolate	Per cent mortality					
		72 h	96 h	120 h	144 h	168 h	Cumulative
44	F463	0.00 (0.00)^{a}	3.33 (6.15)^{abcd}	0.00 (0.00)^{a}	10.00 (18.44)$^{b-fg}$	13.33 (21.14)$^{b-f}$	26.67 (30.79)$^{d-i}$
45	F468	53.33 (46.92)^{n}	0.00 (0.00)^{abc}	16.67 (23.86)^{d}	0.00 (0.00)^{a}	16.67 (23.86)^{cdef}	86.67 (72.78)^{no}
46	F482	0.00 (0.00)^{a}	13.33 (21.15)^{efgh}	0.00 (0.00)^{a}	20.00 (26.07)^{fgh}	10.00 (18.43)$^{b-f}$	43.33 (41.07)^{ghijk}
47	F484	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	3.33 (6.15)^{ab}	6.67 (12.29)^{abcd}	10.00 (18.43)^{de}
48	F486	0.00 (0.00)^{a}	13.33 (21.15)^{efgh}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	20.00 (26.57)^{def}	33.33 (35.22)$^{e-j}$
49	F487	40.00 (39.15)^{jlmn}	13.33 (21.15)^{efgh}	0.00 (0.00)^{a}	6.67 (12.29)$^{a-e}$	0.00 (0.00)^{a}	60.00 (50.94)^{jklm}
50	F490	0.00 (0.00)^{a}	26.67 (30.79)^{hijkl}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	6.67 (12.29)^{abcd}	33.33 (34.93)$^{e-j}$
51	F491	13.33 (21.14)^{cdef}	3.33 (6.15)^{abcd}	0.00 (0.00)^{a}	10.00 (18.44)$^{b-fg}$	23.33 (28.78)^{ef}	50.00 (45.00)^{ijkl}
52	F493	40.00 (39.15)^{jklmn}	36.67 (37.23)^{jkl}	13.33 (21.15)^{cd}	10.00 (18.44)$^{b-fg}$	0.00 (0.00)^{a}	100.00 (90.00)^{p}
53	F498	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	13.33 (21.15)^{defgh}	13.33 (21.14)$^{b-f}$	26.67 (30.79)$^{d-i}$
54	F500	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	13.33 (21.15)^{cd}	0.00 (0.00)^{a}	3.33 (6.14)^{ab}	16.67 (23.86)^{defg}
55	F503	0.00 (0.00)^{a}	3.33 (6.15)^{abcd}	0.00 (0.00)^{a}	3.33 (6.15)^{abc}	3.33 (6.14)^{ab}	10.00 (15.00)^{abcd}
56	F504	40.00 (39.15)^{jklmn}	20.00 (26.07)^{fghijk}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	16.67 (23.86)^{cdef}	76.67 (65.85)^{mn}
57	F505	23.33 (28.78)$^{e-j}$	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	10.00 (18.44)$^{b-fg}$	10.00 (18.43)$^{b-f}$	43.33 (41.15)^{ghijk}
58	F506	23.33 (24.15)^{defgh}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	3.33 (6.15)^{abc}	0.00 (0.00)^{a}	26.67 (26.07)^{defgh}
59	F508	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{ab}
60	F510	10.00 (15.00)^{bcd}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	6.67 (12.29)^{abcd}	16.67 (23.86)^{defg}
61	F514	23.33 (28.78)$^{e-jk}$	10.00 (18.44)^{efg}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	33.33 (35.22)$^{e-j}$
62	HD1	50.00 (45.00)^{mn}	36.67 (37.23)^{jl}	3.33 (6.15)^{ab}	6.67 (12.29)$^{a-e}$	0.00 (0.00)^{a}	96.67 (83.86)^{op}
63	Control	0.00 (0.00)^{a}	0.00 (0.00)^{abc}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.00 (0.00)^{abc}
	F.Pr.	<.001	<.001	<.001	<.001	<.001	<.001
	SeD	4.54	4.94	4.78	5.62	6.25	7.10
	LSD	8.98	9.77	9.46	11.13	12.37	14.06

Figures in parenthesis are angular transofrmed values.
Values followed same letter are not significantly different as per DMRT.

Table 2. Cumulative mortality range of *B. thuringiensis* strains native to forest ecosystem based on their efficacy against *S. litura*

S. No	Mortality range	Strains		
		ID	No. of Strains	Frequency
1	Strains with 0-25 % mortality	F252, F263, F277, F316, F429, F430, F434, F438, F441, F447, F455, F457, F459, F484, F500, F503, F508, F510	18	29.51
2	Strains with 26-50 % mortality	F254, F256, F258, F261, F262, F281, F284, F297, F307, F309, F321, F328, F339, F347, F361, F396, F432, F433, F435, F436, F440, F443, F444, F445, F463, F482, F486, F490, F491, F498, F505, F506, F514	33	54.10
3	Strains with 51-75 % mortality	F268, F323, F399, F437, F462, F487	6	9.84
4	Strains with 76-100 % mortality	F287, F468, F493, F504	4	6.56
		Total	61	100.00

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STUDIES ON GENETIC VARIABILITY IN TWO F_3 POPULATIONS OF GROUNDNUT (*Arachis hypogaea* L.)

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ABSTRACT

The present study aims to reveal the importance of quantitative traits and genetic variability existing in F_3 generation of two crosses, TCGS-1157 × TCGS-1073 and TCGS-1157 × TCGS-1043 of groundnut. The coefficient of variation at genotypic levels were high for number of secondary branches, number of pegs per plant, SLA, SLW, total biomass per plant, shoot weight per plant, number of mature pods per plant, mature pod weight per plant and kernel weight per plant and moderate for number of primary branches per plant, number of immature pods per plant, shelling out-turn and harvest index. Plant height and SCMR at 30 DAS and SCMR 60 DAS showed low GCV. From the results, high heritability coupled with high genetic advance observed for number of secondary branches per plant, number of pegs per plant,, total biomass per plant, shoot weight per plant, mature pods per plant, harvest index, mature pod weight per plant, kernel weight per plant, SLA and SLW indicated the presence of additive gene effects and simple selection would be effective for improvement of these traits

KEYWORDS: Genetic variability, PCV, GCV, heritability, genetic advance, pod yield, groundnut.

INTRODUCTION

Groundnut is not only a major oilseed crop but also an important food crop in India. In India, groundnut occupies an area of 37 lakh ha with a production of 57 lakh tonnes and productivity of 1546 kg ha^{-1} in *kharif* season (2015-16). In *rabi-summer,* it is being grown in 7.4 lakh ha with production of 14.5 lakh tonnes with productivity of 1960 kg ha^{-1} (2015-16). In Andhra Pradesh, in *kharif* season, it is cultivated in an area of 6.8 lakh ha with a production of 5.9 lakh tonnes and productivity of 865 kg ha^{-1}.In *rabi* season it is cultivated in 0.95 lakh ha with a production of 1.98 lakh tonnes and productivity of 2329kg ha^{-1} (Anonymous, 2016).For the improvement and stabilization of yields, in these situations it is necessary to combine the good attributes from Spanish and Valencia bunch types and Virginia types to develop short duration high yielding varieties to fit into the cropping pattern of Andhra Pradesh. In this context, it is necessary to understand genetics of traits that contribute for high yield and good plant type for these two major situations-rainfed and irrigated. Hence, the present study was planned to study genetic parameters in two F_3 populations having common female parent TCGS 1157 (a high yielding short statured variety with 105-115 days duration) and male parents, TCGS 1073 and TCGS 1043.

MATERIALS AND METHODS

The present investigation was carried out at Regional Agricultural Research Station, Tirupati. The experimental material consisted of two F_3 populations *viz.,* TCGS 1157 × TCGS 1043 and TCGS 1157 × TCGS 1073 which were derived from TCGS 1157, TCGS 1043 and TCGS 1073. The F_3 generation of two crosses were raised in unreplicated plots of 5 m length separately along with the parents during *kharif*, 2016. A spacing of 30 cm x 10 cm was adopted. 90-120 random competitive plants were picked up in population of each cross while 30 random competitive plants were taken in each parent for recording observations. Data was recorded for yield, harvest index and water use efficiency related traits *viz.*, number of primary branches per plant, number of secondary branches, plant height, number of pegs, pegs to pod ratio, SLA, SLW, SCMR, total biomass per plant, shoot weight per plant, number of mature pods per plant, number of immature pods per plant, shelling out-turn, harvest index, mature pod weight per plant and kernel weight per plant. The data thus generated were subjected to statistical analysis computation of genetic variability, heritability and genetic advance estimates as per the procedures (Nadarajan and Gunasekaran, 2005).

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RESULTS AND DISCUSSION

The test of heterogeneity of crosses revealed highly significant differences among the two crosses for all 17 characters indicating presence of considerable variation in the breeding material under rainfed conditions. The estimates of genetic parameters are presented in Table 1 Since F_2 generation is a segregating population the range of variability present in all the two crosses was quite high for most of the traits suggesting the application of individual plant selection for high yield and water use efficiency.

In the present study, the estimates of PCV for all the characters were little higher than the estimates of GCV, which may be due to the interaction of genotypes with the environment. The moderate to high estimate of coefficient of variation was registered for number of secondary branches, number of pegs per plant, SLA, SLW, total biomass per plant, shoot weight per plant, number of mature pods per plant, mature pod weight per plant and kernel weight per plant, moderate for number of primary branches per plant, number of immature pods per plant, shelling out-turn and harvest index indicating greater scope of selection for improvement of these characters. Similar results of high estimates of variability were reported by earlier workers for number of secondary branches (Dandu *et al*., 2011; John *et al*., 2012), SLA (Pushpa *et al*., 2014), total biomass per plant (Shinde *et al.,* 2010), number of mature pods per plant and mature pod weight per plant (Padmaja *et al.,* 2013), kernel weight per plant (Ahamed, 1995 and Vishnuvardhan *et al.*, 2012), harvest index (Reddi *et al.,* 1986), number of immature pods per plant (Padmaja *et al.,* 2013), number of primary branches (Vishnuvardhan *et al.,* 2012) and corroborates the findings of the present study.

High heritability coupled with high genetic advance as a per cent of mean were recorded for number of secondary branches per plant, number of pegs per plant, total biomass per plant, shoot weight per plant, mature pods per plant, harvest index, mature pod weight per plant, kernel weight per plant, SLA and SLW which indicated the inheritance of additive gene effects in the genetic control of these traits. Hence, simple selection can be practiced to improve these traits. This was in conformity with the findings of Dandu *et al.* (2011) for number of secondary branches Girdthai *et al.* (2012) for total biomass per plant, Riaz *et al*. (2013) for shoot weight, Sumathi and Ramanathan (1995) for number of mature pods per plant, and Jayalakshmi *et al.* (1998) for mature pods weight per plant. The knowledge on heritability of traits is helpful to decide the selection procedure to be followed to improve the trait in a situation. High heritability recorded in a trait indicates the low influence of environment on expression of the trait. Therefore, for improving these traits the selection will be more effective in early generation on the basis of *per se* performance of these traits. These traits may be improved by mass or progeny selection. High heritability recorded for pod yield per plant suggested that direct selection based on pod yield *per se* could be effective for its genetic improvement. High heritability coupled with moderate genetic advance as per cent of mean was recorded for SPAD chlorophyll reading and pegs/pod ratio. These are more likely to be controlled by both additive and non-additive gene effects. Hence, recombinant selection could be more effective to improve these traits.

CONCLUSION

Based on results of this study, it could be concluded that there was considerable amount of variability present in the both the crosses. To sum up, genotypic co-efficient of variation, heritability and genetic advance as percentage of mean were moderate to high in both crosses for number of secondary branches per plant, pegs per plant, total biomass per plant, shoot weight per plant, mature pods per plant, immature pods per plant, harvest index, mature pod weight per plant, kernel weight per plant, SLA and SLW indicating that these are predominantly governed by additive genetic variance. Hence, it could be inferred that simple phenotypic selection would be effective in early generations in these crosses to make improvement in the characters mentioned above. Conversely, low estimates of GCV, heritability and genetic advance as per cent of mean were registered for SCMR and pegs/pod ratio indicating little scope of improvement of these traits by selection as they are governed by the non-additive gene effects.

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Table 1. Genetic parameters for 17 characters in two F_3 populations of groundnut

Character	Mean	Range	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability %	Genetic advance	Genetic advance as % of mean
Primary branches per plant									
TCGS-1157 × TCGS-1073	4.68	2-8	0.98	0.37	21.20	13.07	38.04	0.78	16.61
TCGS-1157 × TCGS-1043	4.58	3-7	0.54	0.13	16.05	7.77	23.45	0.36	7.75
Secondary branches per plant									
TCGS-1157 × TCGS-1073	3.41	0-7	2.40	1.04	45.51	29.98	43.39	1.39	40.68
TCGS-1157 × TCGS-1043	3.31	0-6	1.21	0.12	33.20	10.66	10.32	0.23	7.06
Plant height (cm)									
TCGS-1157 × TCGS-1073	30.77	22-52	18.62	8.54	14.02	9.50	45.87	4.08	13.25
TCGS-1157 × TCGS-1043	30.17	20-39	17.56	8.42	13.62	9.43	47.93	4.14	13.45
Pegs number per plant									
TCGS-1157 × TCGS-1073	27.54	11-56	64.75	52.99	29.22	26.43	81.83	13.56	49.25
TCGS-1157 × TCGS-1043	26.53	9-68	69.20	51.98	31.35	27.17	75.12	12.87	48.52
Pegs/Pod									
TCGS-1157 × TCGS-1073	1.86(7.81)	6.38-10.18	0.54	0.06	9.41	3.14	11.10	0.17	2.15
TCGS-1157 × TCGS-1043	1.97(8.03)	6.18-11.24	0.73	0.62	10.61	9.83	85.89	1.51	18.77
Total biomass per plant (g)									
TCGS-1157 × TCGS-1073	22.95	8.80-48.70	36.99	26.62	26.50	22.48	71.96	9.02	39.28
TCGS-1157 × TCGS-1043	19.24	8.30-48.60	43.28	32.40	34.19	29.59	74.87	10.15	52.74
Shoot weight per plant (g)									
TCGS-1157 × TCGS-1073	15.78	5.40-53.50	49.07	41.74	44.38	40.93	85.07	12.28	77.78
TCGS-1157 × TCGS-1043	11.68	4.90-34.00	23.75	15.77	41.73	34.01	66.41	6.67	57.09
Mature pods per plant									
TCGS-1157 × TCGS-1073	10.24	3.00-22.00	16.37	9.74	39.51	30.48	59.51	4.96	48.44
TCGS-1157 × TCGS-1043	10.34	3.00-20.00	11.26	3.36	32.45	21.04	42.05	2.91	28.11

Cont...

Table 1. Cont...

Character	Mean	Range	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability %	Genetic advance	Genetic advance as % of mean
Immature pods per plant									
TCGS-1157 × TCGS-1073	4.90	1.00-11.00	4.52	0.48	43.39	14.18	10.68	0.47	9.55
TCGS-1157 × TCGS-1043	3.39	1.00-9.00	3.25	0.27	53.19	15.34	8.32	0.31	9.12
Shelling out-turn (%)									
TCGS-1157 × TCGS-1073	58.33(49.83)	29.40-57.07	18.52	15.08	8.64	7.79	81.40	7.22	14.48
TCGS-1157 × TCGS-1043	54.70(47.72)	33.67-55.37	26.96	23.72	10.88	10.21	87.99	9.41	19.72
Harvest index (%)									
TCGS-1157 × TCGS-1073	43.29(41.09)	30.74-55.06	23.60	20.52	11.82	11.02	86.95	8.70	21.17
TCGS-1157 × TCGS-1043	47.26(43.40)	29.76-55.26	28.83	25.61	12.37	11.66	88.84	9.83	22.64
Mature pod weight per plant (g)									
TCGS-1157 × TCGS-1073	8.60	2.10-18.70	7.55	4.34	31.96	24.22	57.41	3.25	37.79
TCGS-1157 × TCGS-1043	10.76	2.70-20.00	10.76	7.08	41.57	33.71	65.78	4.45	56.33
Kernel weight per plant (g)									
TCGS-1157 × TCGS-1073	5.01	1.10-10.80	2.86	2.02	33.78	28.38	70.61	2.46	49.13
TCGS-1157 × TCGS-1043	4.23	1.10-12.10	2.87	1.94	40.04	32.94	67.67	2.36	55.82
SCMR (30 days)									
TCGS-1157 × TCGS-1073	45.35	30.50-66.80	14.47	10.05	8.39	6.99	69.45	5.44	12.00
TCGS-1157 × TCGS-1043	43.79	6.3-55.1	15.40	5.74	8.96	5.47	37.26	3.01	6.88
SCMR (60 days)									
TCGS-1157 × TCGS-1073	48.47	30.00-58.70	29.41	20.30	11.19	9.30	69.03	7.71	15.91
TCGS-1157 × TCGS-1043	47.65	32.40-58.40	21.64	7.96	9.76	5.92	36.77	3.52	7.39
SLA									
TCGS-1157 × TCGS-1073	145.96	41.18-342.90	2140.28	1434.08	31.70	25.95	67.00	63.86	43.75
TCGS-1157 × TCGS-1043	148.00	72.57-371.50	1510.65	931.07	26.26	20.62	61.63	49.35	33.34
SLW									
TCGS-1157 × TCGS-1073	0.01	0.00292-0.02	0.0000063	0.0000045	33.18	28.04	71.42	0.003695	48.81
TCGS-1157 × TCGS-1043	0.0072	0.00269-0.01378	0.0000031	0.0000019	24.67	19.14	60.23	0.002201	30.61

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EVALUATION OF YIELD, DRY MATTER ACCUMULATION AND LEAF AREA INDEX IN MAIZE HYBRIDS AS AFFECTED BY DATES OF SOWING

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ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station Farm, Tirupati during *kharif* season, 2016, to know the influence of dates of sowing on Leaf Area Index (LAI), dry matter accumulation and yield of different maize hybrids. The experiment was laid out in a split plot design with twelve treatments and replicated thrice. The three hybrids (D.S 900M, Pinnacle and CP818) are major treatments and sub treatments are four dates of sowing (June II FN, July I FN, July II FN and August I FN). Among the hybrids higher leaf (15.6 g plant^{-1}), stem (78.9 g plant^{-1}), tassel (2.6 g plant^{-1}) and cob weight (177 g plant^{-1}) was observed in D.S 900M on par with Pinnacle and CP818. Pinnacle recorded numerically higher yield (3006.58 kg ha^{-1}) than D.S 900 M (2748 kg ha^{-1}) but was significantly higher than CP818 (2678.4 kg ha^{-1}). Among the dates of sowing D_1 (June II FN) recorded significantly higher yield (3684.36 kg ha^{-1}) than D_2 (3207.72 kg ha^{-1}), D_3 (2628 kg ha^{-1}) and D_4 (1724.26 kg ha^{-1}). The higher yield was attributed to the favorable agro-climatic conditions particularly temperature, day length and sunshine hours. Hence, the hybrid Pinnacle sown at June II FN gave the best yield compared to the other interactions of hybrids and dates of sowing.

KEYWORDS: Maize, LAI, Yield

INTRODUCTION

Maize is the third most important cereal crop species in the world after wheat and rice. It is grown across a wide range of climates, but mainly in the warmer temperate regions and humid subtropics. Maize is cultivated on nearly 178 m ha in about 160 countries and contributes to 50 per cent to the global grain production. In India maize constitutes 9 per cent of total volumes of cereals and is third most important crop after rice (42%) and wheat (32%). In India maize is cultivated in an area of about 9.72 ha with production of 24.35 lakh tons and productivity of 2583 kg ha^{-1}. In Andhra Pradesh it is cultivated in an area of 864 ha with production of 3658 tons and productivity of 4234 kg ha^{-1} (Anonymous, 2014).

The Phenology, dry matter accumulation and yield of a crop is determined by adaptation to a region, its ability to mature and set grain within a growing season, and the synchrony of key developmental phases with ambient environmental conditions critical for productivity. The yield of the plant varies with the cultivar, planting date and growing condition. Hence, it is necessary to follow proper planting dates for different genotypes over temporal and spatial separations.

MATERIALS AND METHODS

The experiment was laid out in a split plot design with twelve treatments and replicated thrice. Tree hybrids *viz.,*D.S 900M , Pinnacle and CP818 were considered as major treatments and four dates of sowing *viz.,*June II FN, July I FN, July II FN and August I FN were considered as sub treatments. Sampling was done at different phenological growth stages of crop. Three plants from each treatment or plot were dug out with roots. The plants were thoroughly washed to free from dirt and surface dried with blotting paper. Different plant parts were dried in hot air oven at 100°C for 15 minutes and then at 80°C for 48 hours until they attained constant weights. Leaf area was estimated in three plants in each plot at different phenological growth stages of crop. After separation of leaves from the plant, leaf area was estimated using leaf area meter (Li-COR model LI 3100) and expressed as cm^2 plant^{-1}. Leaf area index was calculated by using the formula proposed by Watson (1952).

RESULTS AND DISCUSSION

Leaf area Index

Irrespective of hybrids and dates of sowing LAI increased as the growth advanced. The exponential

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Table 1. Leaf Area Index (LAI) of maize hybrids sown at different dates of sowing

Treatments	6 leaf stage	Tasseling stage	Silking stage	Soft dough stage	Hard dough stage	Physiological maturity
Hybrids						
D.S 900M (H_1)	0.42	2.3	2.2	1.6	1.1	0.043
Pinnacle (H_2)	0.39	2.4	2.8	1.7	1.2	0.041
CP818 (H_3)	0.41	2.1	2.1	1.6	1	0.04
CD (P=0.05)	NS	NS	0.12	NS	0.06	0.001
Dates of Sowing						
June II FN (D_1)	0.69	3.7	3.8	2.5	2.1	0.052
July I FN (D_2)	0.42	2.3	2.2	1.7	1.0	0.042
July II FN (D_3)	0.29	1.6	1.6	1.1	0.7	0.041
August I FN (D_4)	0.22	1.2	1.1	1.0	0.5	0.029
CD (P=0.05)	0.14	0.44	0.25	0.074	0.12	0.002

Table 2. Dry matter partitioning (g plant^{-1}) of maize hybrids sown at different dates of sowing

Treatments	Leaf dry weight	Stem dry weight	Tassel dry weight	Cob weight	Total dry matter
Hybrids					
D.S 900M (H_1)	15.6	78.9	2.6	177	274.1
Pinnacle (H_2)	11.9	77.5	2.5	181.2	273.1
CP818 (H_3)	12.2	76.5	2.3	175.2	266.2
CD (P=0.05)	0.7	NS	0.1	2.3	3.1
Dates of Sowing					
June II FN (D_1)	21.6	95.9	3.1	193.2	313.8
July I FN (D_2)	12.6	83.6	2.7	183.4	282.3
July II FN (D_3)	10.1	71.7	2.2	172	256
August I FN (D_4)	8.8	59.6	1.8	162.5	232.73
CD (P=0.05)	1.2	3.1	0.1	3.1	4.1

Table 3. Grain yield (kg ha^{-1}) of maize hybrids at different dates of sowing

Treatments	Kernel yield (kg ha^{-1})
Hybrids	
D.S 900M (H_1)	2748.9
Pinnacle (H_2)	3006.6
CP818 (H_3)	2678.4
CD (P=0.05)	304.7
Dates of sowing	
June II FN (D_1)	3684.4
July I FN (D_2)	3207.7
July II FN (D_3)	2628.8
August I FN (D_4)	1724.3
CD (P=0.05)	238.8

increase in LAI was observed from six leaf stage to silking stage thereafter it was decreased.

Among the hybrids maximum LAI was recorded by Pinnacle (2.8) followed by D.S 900M (2.2) and CP818 (2.1). Radiation interception largely determines LAI. In Pinnacle it was significantly higher at silking, hard dough and physiological maturity stages (Table 1).

Among the dates of sowing D_1 (June II FN) recorded significantly highest LAI (3.8) followed by D_2 (July I FN, 2.2), D_3 (July II FN, 1.6) and the lowest LAI was recorded in D_4 (August I FN, 1.1) at all the growth stages of maize. The present results are in conformity with the finding of Zaker *et al.* (2014).

Total dry matter (g plant^{-1})

The total dry matter of any variety at a given temperature and photoperiod denotes its source strength. Total dry matter of maize hybrids sown at different dates of sowing increased significantly throughout the growth stages. The variability for total dry matter ranged from 266.2 g to 274.1 g at harvest. Highest total dry matter was recorded by D.S 900M (274.1g) which was on par with Pinnacle (273.1 g) and CP818 (266.2 g) respectively (Table 2).

Among the dates of sowing total dry matter increased exponentially from six leaf stage to physiological maturity. Significantly highest total dry matter was observed in D_1 (June II FN) sowing (313.8 g) followed by D_2 (July I FN) sowing (282.3 g) and D_3 (July II FN) sowing (256 g) and the lowest was recorded in D_4 (August I FN) sowing (232.7 g) at physiological maturity. Similar results were reported by Nielson *et al*. (2002) and Sulochana *et al*. (2015).

Yield (kg ha^{-1})

Among the hybrids Pinnacle recorded numerically higher yield (3006.58 kg ha^{-1}) than D.S 900 M (2748 kg ha^{-1}) but was significantly higher than CP818 (2678.4 kg ha^{-1}). Due to increased heat use efficiency in case of Pinnacle total kernel yield increased since the grain yield is linearly related to heat use efficiency (Table 3).

Among the dates of sowing D_1 (June II FN) recorded significantly higher yield (3684.36 kg ha^{-1}) than D_2 (3207.72 kg ha^{-1}), D_3 (2628 kg ha^{-1}) and D_4 (August I FN) recorded significantly lower yields (1724.26 kg ha^{-1}). The higher yields attributed to the favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of higher accumulated Growing Degree days (GDD), Photo thermal Units (PTU) and Helios Thermal Units (HTU) from sowing to physiological maturity compared to other dates of sowing. The results are in conformity with the Hossein *et al.* (2014), Zaker *et al.* (2014) and Sulochana *et al*. (2015).

CONCLUSION

Pinnacle proved to be superior and better adapted to southern agro climatic conditions compared to D.S 900M and CP818. Sowing of maize hybrids during June II FN was found to be appropriate interms of higher physiological efficiency and yields.

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IN VITRO SCREENING OF ANTAGONISTIC *Trichoderma* spp. ISOLATES AGAINST *Macropomina phaseolina*

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ABSTRACT

Six isolates of *Trichoderma* spp. were tested for their antagonist potential against four isolates of *M. phaseolina*, incitant of groundnut dry root rot by following dual culture technique *in vitro*. Among all the isolates of *Trichoderma,* GRT5 shown highest (59.48%) mean inhibition followed by GRT2 (59.38%), GRT1 (59.27%) and GRT4 (58.96%). From the above study top four isolates of *Trichoderma* spp. which showed maximum mean inhibition per cent when dual cultured with four isolates of *M. phaseolina viz.,* GRT5, GRT2, GRT1 and GRT4 were considered as effective *Trichoderma* isolates and one isolate of pathogen i.e., SmMp was considered as a more virulent pathogen which exhibited lowest mean percent inhibition (56.81%) in dual culture.

KEYWORDS: *Tricoderma* spp. *M. Phaseolina*, Dual culture, Inhibition percent and Dry root rot.

INTRODUCTION

Groundnut is a major oil seed crop in India covering an area of 4.59 M ha with a production of 6.73 M t averaging a productivity of 1.46 t ha^{-1}. In Andhra Pradesh, it is grown over an area of 0.77 M ha with a production of 0.80 M t and productivity of 1.03 t ha^{-1} (Commodity Market of India, 2016). In Andhra Pradesh, majority of groundnut crop is cultivated during *kharif* in Anantapuramu, Chittoor, Kurnool, Kadapa districts occupying 97.42 per cent area of the total groundnut growing area in Andhra Pradesh (Anonymous, 2014-15).

Several factors such as water stress, pests, and diseases are responsible for the low productivity of groundnut in A.P (1.03 t ha^{-1}) compared with national average (1.46 t ha^{-1}). Diseases such as late leaf spot (*Phaeoisariopsis personata),* collar rot *(Aspergillus niger),* stem rot (*Sclerotium rolfsii*) and dry root rot (*M. phaseolina)* are of major concern among fungal diseases.

In groundnut, *M. phaseolina* is known to cause root, stem, peg and pod rots and leaf spots on seedlings and on older plants. It also causes seedling blight, root rot and charcoal rot diseases on more than 500 plant species from more than 100 families distributed worldwide. The disease appears in hot and dry weather when soil temperature is 80-95°F (27-35°C) for 2-3 weeks. The disease control is inefficient or difficult by using the chemical fungicides. The fungus is a facultative parasite capable of living saprophytically on dead organic tissue, particularly on many of its natural hosts producing sclerotial bodies. The fungus is mainly a soil dweller and spreads from plant to plant through irrigation water and implements and cultural operation. The sclerotia and pycniospore may also become air borne and cause further spread of the pathogen (Rangaswami and Mahadevan, 2008).

Biological control seems to offer a practicable approach. As biological control has several advantages (when applied either alone or in combination with other management practices) like ecofriendly, effective against soilborne diseases and having growth promoting activity which cannot be possible by chemicals.

Biocontrol agents like *Pseudomonas fluorescens* and *Trichoderma* spp. have been assessed for their efficacy against *M. phaseolina* and *S. rolfsii* (Ganasen and Sekar, 2012; Monali *et al*., 2016).

Application of two different biocontrol agents or two strains of the same biocontrol agent with different mechanisms of action gives the advantage of complementing each other in nullifying the deleterious effect of plant pathogens (Mishra *et al.,* 2013; Rajasekhar *et al*., 2016).

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MATERIALS AND METHODS

Screening of *Trichoderma* isolates for their antagonistic potential against *M. phaseolina* was done using dual culture method (Morton and Straube, 1955).

For finding the potential fungal antagonist against test pathogen, 5 mm mycelial disc of fungal antagonist was placed at 1 cm away from the periphery of 9 cm sterile Petri plate containing 20 ml of sterile PDA. Then, 5mm mycelial disc of the test pathogen was placed opposite to the mycelial disc of fungal antagonist at 1cm away from the periphery of Petri plate. The plates were kept in incubator at 25 ± 2°c for incubation. Readings were recorded when the pathogen in the monoculture grown fully.

Per cent inhibition of mycelial growth of test pathogen over control was calculated by the formula given by Vincent (1927).

$$I=\frac{C-T}{C}X100$$

where,

I = Per cent reduction in growth of test pathogen.

C = Radial growth (mm) in monocultured check.

T = Radial growth (mm) in dual cultured plates.

RESULTS AND DISCUSSION

Six isolates of *Trichoderma* spp. were tested for their antagonist potential against four isolates of *M. phaseolina*, incitant of groundnut dry root rot following dual culture technique *in vitro*. The results were analysed using two factorial CRD and were represented in Table 3. 1.

Among the six isolates of *Trichoderma* spp. tested against the four isolates of *M. phaseolina*, maximum mean inhibition per cent (59.48%) was observed with the GRT5 isolate followed by GRT2 (59.38%), GRT1 (59.27%), GRT4 (58.96%) and GRT6 (58.13%). The isolate GRT5 significantly differed with GRT6 and GRT3 isolates and on par with GRT2, GRT1 and GRT4 isolates. Lowest mean inhibition per cent (58.02%) was observed with the GRT3 isolate, which significantly differed with the GRT5, GRT2 and GRT1 isolates, insignificant with the GRT4 and GRT6 isolates.

Interaction effects between RgMp isolate of pathogen dual cultured with the all the six isolates of *Trichoderma* spp. revealed that maximum inhibition per cent (67.92%) was observed with the GRT5 isolate followed by GRT2 (62.92%), GRT4 (61.67%), GRT3 (60.42%), GRT1(58.75%) and GRT6 (57.50%) isolates. The isolate GRT5 significantly differed with the all the remaining isolates. Lowest inhibition per cent (57.50%) was observed with GRT6 isolate, which significantly differed with all the remaining isolates of *Trichoderma* spp. except isolate GRT1.

When TpMp isolate of pathogen dual cultured with all the six isolates of *Trichoderma* spp. maximum inhibition per cent (61.25%) was observed with the isolate GRT6 followed by GRT1 (58.75%), GRT5 (58.33%), GRT4 (57.92%) and GRT3 (56.67%) isolates. The isolate GRT6 significantly differed with all the remaining isolates of *Trichoderma* spp. The lowest inhibition per cent (55.42%) was observed with the isolate GRT2, which significantly differed with the other remaining isolates except isolate GRT3.

Interaction effects between SgMp and all the six isolates of *Trichoderma* spp. revealed that maximum inhibition per cent (60.42%) was observed with GRT1, GRT2 and GRT4 isolates of *Trichoderma* which insignificantly differed among them and also with other remaining isolates of *Trichoderma* spp. except GRT5 (55.83%). Lowest inhibition per cent (55.83%) was observed with the isolate GRT5, which significantly differed with the all the remaining isolates of *Trichoderma* spp.

Results from dual culture interaction studies in case of SmMp isolate and six isolates of *Trichoderma* spp., revealed that maximum inhibition per cent (59.17%) was observed with isolate GRT1 followed by GRT2 (58.75%), GRT3 (56.67%), GRT4 (55.83%) and GRT5 (55.83%). Lowest inhibition per cent (54.58%) was observed with isolate GRT6.

From the above study top four isolates of *Trichoderma* spp. which showed maximum mean inhibition per cent when dual cultured with four isolates of *M. phaseolina viz.,* GRT5, GRT2, GRT1 and GRT4 were considered as effective *Trichoderma* isolates. Besides the one isolate of pathogen which showed lowest mean per cent inhibition (56.81%) in dual culture i.e., SmMp was considered as virulent pathogen.

Table 1. *In vitro* evaluation of efficacy of antagonistic *Trichoderma* spp. isolates against *M. phaseolina* in dual culture technique

Treatments	RgMp		TpMp		SgMp		SmMp		Mean A	
	Radial growth of the pathogen (cm)	Per cent inhibition over control	Radial growth of the pathogen (cm)	Per cent inhibition over control	Radial growth of the pathogen (cm)	Per cent inhibition over control	Radial growth of the pathogen (cm)	Per cent inhibition over control	Radial growth of the pathogen (cm)	Per cent inhibition over control
GRT1	3.30	58.75 (50.02)	3.30	58.75 (50.02)	3.17	60.42 (50.99)	3.27	59.17 (50.26)	3.26	59.27^{abc} (50.32)
GRT2	2.97	62.92 (52.47)	3.57	55.42 (48.09)	3.17	60.42 (51.00)	3.30	58.75 (50.02)	3.25	59.38^{ab} (50.39)
GRT3	3.17	60.42 (51.00)	3.47	56.67 (48.81)	3.33	58.33 (49.78)	3.47	56.67 (48.81)	3.36	58.02^{de} (49.60)
GRT4	3.07	61.67 (51.73)	3.37	57.92 (49.54)	3.17	60.42 (50.99)	3.53	55.83 (48.33)	3.28	58.96^{abcd} (50.15)
GRT5	2.57	67.92 (55.48)	3.33	58.33 (49.78)	3.53	55.83 (48.33)	3.53	55.83 (48.33)	3.24	59.48^{a} (50.48)
GRT6	3.40	57.50 (49.30)	3.10	61.25 (51.48)	3.27	59.17 (50.27)	3.63	54.58 (47.61)	3.35	58.13^{de} (49.66)
Mean B	3.08	61.53^{a} (51.67)	3.36	58.06^{c} (49.62)	3.27	59.10^{b} (50.23)	3.46	56.81^{d} (48.89)		
M. phaseolina monoculture	8.00	0.00								
Factors	**C.D (P=0.01)**	**C.D (P=0.01)**	**SEm±**	**SEm±**						
Trichoderma spp. Isolates	0.09	1.12	0.03	0.39						
M. phaseolina Isolates	0.07	0.91	0.03	0.32						
Interactions	0.18	2.24	0.06	0.78						

*Values are the means of three replications; Values in the parenthesis are angular transformed values

The results were in agreement with the findings of Karthikeyan *et al*. (2006) who reported that *T. viride* (Tv1) and *T. harzianum* were most effective in reducing the mycelial growth and sclerotial formation of *M. phaseolina* causing dry root rot of groundnut. They also reported that volatiles of Tv1 had shown greater fungistatic effect on *M. phaseolina* under *in vitro* conditions.

Ramezani (2008) studied efficacy of four fungal bioagents *viz., T. hamatum, T. harzianum*, *T. polysporum* and *T. viride* under *in vitro* conditions against the brinjal root rot pathogen, *M. phaseolina.* He reported that *T. harzianum* produced the maximum inhibition zone of 18.20 per cent compared to the minimum of 7.30 per cent by *T. hamatum*.

SUMMARY AND CONCLUSION

Among the six *Trichoderma* isolates tested against four isolates of *M. phaseolina*, isolate GRT5 was superior with highest (59.48%) mean inhibition followed by GRT2 (59.38%), GRT1 (59.27%) and GRT4 (58.96%) isolates which were on par with each other. From the above results top four isolates of *Trichoderma* spp. which showed maximum mean inhibition per cent when dual cultured with four isolates of *M. phaseolina viz.,* GRT5, GRT2, GRT1 and GRT4 were considered as effective *Trichoderma* isolates. Besides this one isolate of pathogen i.e., SmMp was considered as a more virulent pathogen which showed lowest mean percent inhibition (56.81%) in dual culture.

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ORGANIC APPROACH FOR SUSTAINED PRODUCTIVITY OF *RABI* GROUNDNUT (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted at the dry land farm of S.V. Agricultural College, Tirupati during *rabi,* 2016 to study the effect of organic manures *viz.,* FYM and neem cake and organic sources *viz.,* Panchagavya, Jeevamrutha and Ghanajeevamrutha along with 100 per cent recommended dose of fertilizers on growth, yield attributes and yield of groundnut. Application of 100 per cent recommended dose of fertilizers (30-40-50 kg N, P_2O_5 and K_2O ha^{-1}) resulted in improved growth parameters, yield attributes and yield of groundnut. Among the organic sources tested, application of 100 per cent N through FYM (60 %) + Neem cake (40 %) + Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 % at every 10 days interval up to 15 days before harvest recorded significantly higher growth parameters, yield attributes and yield of groundnut compared to application of 100 per cent N through FYM (60 %) + Neem cake (40 %).

KEYWORDS: Groundnut, Organic manures, Panchagavya, Jeevamrutha, Ghanajeevamrutha, Yield attributes and Yield.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is considered to be one of the most important food legume and oilseed crops in India, which is cultivated over an area of 4.7 m ha, with a production of 7.4 m t and average productivity of 1552 kg ha^{-1}. Groundnut is an exhaustive crop and removes large quantities of nutrients from the soil (Kachot *et al.,* 2001). The factors responsible for low yields in groundnut are inadequate and imbalanced use of nutrients (Rao and Shaktawat, 2005). Adequate fertilization in the form of application of organic manures not only improve yield but also maintains soil health and sustains the soil productivity (Lourduraj, 1999). The ever- increasing cost of chemical fertilizer has made it to be realized once again that organic material will have to be utilized judiciously to maintain and improve the soil fertility and productivity. Hence, an attempt was made to investigate the effect of organic sources on the productivity of *rabi* groundnut.

MATERIAL AND METHODS

A field experiment was carried out during *rabi*, 2016 at the dry land farm of S.V. Agricultural College, Tirupati. The experimental soil was sandy loam in texture, neutral in reaction (pH 6.8), low in organic carbon (0.42 per cent) and available nitrogen (142 kg ha^{-1}), medium in available phosphorus (34 kg ha^{-1}) and available potassium (174 kg ha^{-1}). The experiment was laid out in a randomized block design with three replications. The experiment consisted of nine treatments *viz.,* Control (T_1), 100 per cent RDF (30-40-50 kg N, P_2O_5 & K_2O ha^{-1}) (T_2), 100 per cent N through FYM (60%) + Neem cake (40%) (T_3), Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha @ 500 l ha^{-1} before sowing, at every 10 days interval upto 15 days before harvest (T_4), Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} at the time of sowing + Foliar spray of jeevamrutha @ 500 l ha^{-1} at every 10 days interval up to 15 days before harvest (T_5), Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 % at every 10 days interval up to 15 days before harvest (T_6), 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha @ 500 l ha^{-1} before sowing, at every 10 days interval up to 15 days before harvest (T_7), 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} at the time of sowing + Foliar spray of jeevamrutha @ 500 l ha^{-1} at every 10 days interval up to 15 days before harvest (T_8), 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Foliar

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spray of panchagavya @ 3 % at every 10 days interval up to 15 days before harvest (T_9). FYM and neem cake were applied based on per cent of nitrogen content. FYM contains 0.5% N and neem cake contains 1.9% N and these organic manures were applied to the field 15 days before sowing for decomposition. The test variety used in the present experiment was Dharani by adopting spacing of 22.5 cm x 10 cm.

Panchagavya stock solution was prepared by using the following ingredients. Cow dung 7 kg and 1 kg cow ghee were mixed well and kept for 2 days and 2 l of cow urine and 10 l of water were added to the mixture and left for 15 days. Then 2 l of cow milk + 2 l of curd + 2 l of tender coconut water + 250 g black jaggary + 12 no. of ripened bananas were added to accelerate the fermentation. All the materials were added to a wide mouthed pot and kept under shade. The mixture was left for 14 days and stirred twice a day for about 20 minutes both in the morning and evening and then filtered. Before spraying in the field, three per cent spray solution was prepared by mixing 30 ml of panchagavya in 1000 ml of water and it was applied as foliar spray @ 500 l ha^{-1} at 10 days interval starting from 10 DAS to 15 days before crop harvest.

Jeevamrutha was prepared by using the following ingredients. A plastic drum of 200 l capacity was filled with 90 l of water. Cow dung 5 kg was mixed with 10 l of water in a bucket and this mixture was added to drum followed by stirring with long stick. Then 5 l of cow urine was poured slowly with continuous stirring. Black jaggery 1 kg was pounded to powder and added to drum with continuous stirring. Horse gram flour (1kg) was added slowly to the mixture with stirring to avoid formation of clumps. One handful of fertile soil was added to the above mixture as source of beneficial micro-organisms. Jeevamrutha was stirred well until the mixture became homogenous. The drum was covered with plastic lid and was incubated for 5-6 days. Jeevamrutha was stirred twice a day both morning and evening during the incubation period. After 6-8 days, jeevamrutha was applied to soil or as foliar spray depending on the treatment @ 500 l ha^{-1} at 10 days interval starting from 10 DAS to 15 days before crop harvest.

Ghanajeevamrutha was prepared by using following ingredients. Initially 50 kg cow dung was spread on the polythene sheet. Black jaggery 1 kg was pounded to powder and added to cow dung and mixed well. Horsegram flour (1 kg) was added slowly to the mixture with hand mixing to avoid formation of lumps. One and half handful of fertile soil was added to the above mixture and mixed thoroughly until it became homogenous. Then measured quantity of cow urine (2.5 l) was added to the above mixture and this mixture was allowed to dry under the shade for 6-7 days. After a week, ghanajeevamrutha was applied to soil @ 500 kg ha^{-1} at the time of sowing as per the treatments.

RESULTS AND DISCUSSION

Growth parameters and yield attributes

Application of 100 per cent recommended dose of fertilizers (30-40-50 kg N, P_2O_5 and K_2O ha^{-1}) significantly improved all the growth parameters of groundnut viz., plant height, LAI and dry matter production at all the stages of crop growth due to adequate supply of NPK and the major plant nutrients (Table 1) (Zalate and Padmani, 2009). Among the organic sources tested, 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 % at every 10 days interval up to 15 days before harvest recorded improved growth parameters of groundnut *viz.,* plant height, LAI and dry matter production at all the stages of crop growth due to presence of organic manures in slow conversion of organic forms of plant nutrients (all essential nutrients) into available forms and improvement in soil physical and physico - chemical conditions and biological soil properties which might have contributed for improvement in crop growth and development (Kumar *et al.,* 2012), and Panchagavya spray was known to produce bioactive substances secreted by beneficial microorganisms like *Pseudomonas, Azatobacter* and phosphobacteria. These growth promoting secretions might have contributed to improved growth parameters of groundnut (Xu *et al.,* 2000).

Application of 100 per cent RDF improved the yield attributes *i.e*. number of pods $plant^{-1}$, hundred pod weight, hundred kernel weight and shelling per cent due to favourable effect of readily available nutrients with 100 per cent RDF (T_2) is evident with higher dry matter accumulation and effective translocation of photosynthates to the sink (Lourduraj and Rajagopal, 1996). Among the organic sources tested, 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Foliar spray of

Table 1. Effect of different organic sources on growth parameters of groundnut

Treatments	Plant height (cm)	Leaf area (cm^2)	Drymatter production (kg ha^{-1})
T_1 : Control	16.2	0.89	3862
T_2 : 100 per cent RDF (30-40-50 kg N, P_2O_5 & K_2O ha^{-1})	24.1	2.19	6782
T_3 : 100 per cent organic N through FYM (60%) + Neem cake (40%)	20.4	1.54	6259
T_4 : Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha@ 500 l ha^{-1}	19.2	1.12	5755
T_5 : Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} + Foliar spray of jeevamrutha @ 500 l ha^{-1}	19.5	1.22	5867
T_6 : Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 %	21.2	1.78	6532
T_7 : T_3 + T_4 = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha@ 500 l ha^{-1})	19.8	1.33	5982
T_8 : T_3 + T_5 = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} + Foliar spray of jeevamrutha @ 500 l ha^{-1})	20.1	1.43	6198
T_9 : T_3 + T_6 = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 %)	22.2	2.05	6659
S.Em ±	0.19	0.03	38.5
CD (P = 0.05)	0.57	0.11	116

Table 2. Effect of different organic sources on yield attributes and yield of groundnut

Treatments	Number of pods plant^{-1}	Hundred pod weight (g)	Hundred kernel weight (g)	Shelling percentage (%)	Pod yield (kg ha^{-1})	Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1 : Control	15.2	87.5	28.7	63.5	1140	724	1631
T_2 : 100 per cent RDF (30-40-50 kg N, P_2O_5 & K_2O ha^{-1})	34.7	113.8	42.2	73.0	2533	1850	3472
T_3 : 100 per cent organic N through FYM (60%) + Neem cake (40%)	24.3	103.5	33.5	70.5	1852	1306	2317
T_4 : Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha@ 500 l ha^{-1}	20.4	99.5	31.2	66.8	1438	961	1948
T_5 : Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} + Foliar spray of jeevamrutha @ 500 l ha^{-1}	21.4	100.6	31.8	67.4	1547	1043	2009
T_6 : Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 %	27.7	106.4	36.4	71.3	2054	1465	2645
T_7 : $T_3 + T_4$ = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Soil application of jeevamrutha@ 500 l ha^{-1})	22.4	101.5	32.5	68.6	1655	1136	2110
T_8 : $T_3 + T_5$ = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Soil application of ghanajeevamrutha @ 500 kg ha^{-1} + Foliar spray of jeevamrutha @ 500 l ha^{-1})	23.3	102.6	32.9	69.0	1756	1211	2207
T_9 : $T_3 + T_6$ = (100 per cent organic N through FYM (60%) + Neem cake (40%)) + (Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 %)	31.5	110.2	39.7	71.7	2333	1672	3010
S.Em ±	0.34	0.42	0.61	0.84	65.9	52.0	59.2
CD (P = 0.05)	1.0	1.3	1.8	2.5	198	157	179

panchagavya @ 3 % at every 10 days interval up to 15 days before harvest recorded improved yield attributes *i.e*. number of pods plant^{-1}, hundred pod weight, hundred kernel weight and shelling per cent due to application of organic manures which besides supplying N, P, K, secondary and micro nutrients, also improved the soil condition, which enhanced the root proliferation and source to sink relationship (Choudhary *et al.,* 2014). Panchagavya included coconut water which contain kinetin and hence increased the cytokinin content in leaf, which in turn increased the chlorophyll content and photosynthetic activity and reflected through the inflated stature of all the yield attributes (Mavarkar *et al.,* 2016).

Yield

Pod and kernel yield significantly improved with the application of 100% recommended dose of fertilizers (30-40-50 kg N, P_2O_5 and K_2O ha^{-1}) over the control due to the reason that fertilizers can supply the required quantity of nutrients instantly in a balanced proportion coinciding with the crop requirement (Thomas and Thenua *et al.,* 2010) (Table 2). Among the organic sources tested, 100 per cent N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 % at every 10 days interval up to 15 days before harvest recorded higher pod yield due combined application of organic manures which might have improved the soil environment which encouraged better root spread resulting in better absorption of nutrients from lower layers which led to the higher pod yield. The seed treatment with ghanajeevamrutha might have increased the activity of microbes there by solubalisation and uptake of nutrients were enhanced (Manjunatha *et al.,* 2009). The easy transfer of nutrients to plant through foliar spray of panchagavya, which contains several nutrients *viz*. macronutrients like nitrogen, phosphorus, potassium and micronutrients required for the growth and development of plants, various aminoacids, vitamins and growth regulators like auxins, gibberellins might have influenced the necessary growth and development in plants which lead to higher pod yield (Somasundaram *et al*., 2007).

CONCLUSION

In conclusion, application of 100 per cent recommended dose of fertilizers (30-40-50 kg N, P_2O_5 and K_2O ha^{-1}) (T_2) appears necessary for *rabi* groundnut for realizing higher crop growth and productivity Among the organic sources tested, 100 per cent organic N through FYM (60%) + Neem cake (40%) + Seed treatment with ghanajeevamrutha + Foliar spray of panchagavya @ 3 % (T_9) resulted in optimum crop growth, yield attributes and pod yield compared to other treatments.

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EFFECT OF CHEMICALS AND *TRICHODERMA* ISOLATES AGAINST SOIL BORNE PATHOGENS IN GROUNDNUT UNDER *IN VITRO* CONDITION

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ABSTRACT

Seven different fungicides were tested against colony growth of *Rhizoctonia bataticola* and *Sclerotium rolfsii.* Among all the fungicides tested, hexaconazole 5% SC, tebuconazole 250 EC, vitavax power 75% WP at all concentrations recorded maximum inhibition (100%) against *Sclerotium rolfsii* and against *Rhizoctonia bataticola*. The per cent inhibition ranged from 97.7 to 100 per cent. Among different *Trichoderma* isolates tested, significant reduction of radial growth of *Rhizoctonia bataticola* and *Sclerotium rolfsii* was recorded by isolates CT7 and CT8.

KEYWORDS: Fungicides, *Trichoderma*, siol born pathogens

INTRODUCTION

Diseases caused by soil-borne fungi are a limiting factor in groundnut production in most of the groundnut growing areas in India. Among the soil-borne fungi, dry root rot (*Rhizoctonia bataticola*), stem rot (*Sclerotium rolfsii*) causes significant economic loss. Though the fungus is seed and soil borne (Dhingra and Sinclair, 1995), soil borne inoculum is more important in causing infection and disease development. Traditionally farmers rely on chemicals for the management of soil borne pathogen. In recent years, alternative ways of management of soil pathogens such as use of bio control agents, green chemicals *etc*., is gaining momentum due to deleterious effect of synthetic chemicals on environment along with various health and safety issues (Ramarethinum *et al.,* 2001).

MATERIALS AND METHODS

Isolation and identification of *Trichoderma* bio-control agents

Fungal bio-control agents (*Trichoderma* spp.) were isolated by using serial dilution technique from rhizophere soil of groundnut from different mandals of Chittoor district and identified based on morphological characters fungi (Rifai, 1969; Bhagat and Pan, 2010).

In vitro evaluation of different fungicides against stem rot and dry root rot pathogens of groundnut

Poisoned food technique was carried out using seven fungicides *viz.,* mancozeb 75% WP, tebuconazole 2 DS [Raxil], carbendazim 50% WP, SAFF 75% WP, hexaconazole 5% SC, tebuconazole 250 EC, Vitavax power 75% WP, to evaluate the colony growth of *Rhizoctonia bataticola* and *Sclerotium rolfsii* separately (Table 1 and 2). All the fungicides were tested at concentrations of 500,1000,2000,3000 and 4000 ppm in autoclaved potato dextrose agar media by poisoned food technique. All the treatments were randomized thrice in completely randomized design and incubated at 28ºC. Radial growth of fungus was recorded after 7-10 days of incubation when the fungal growth was covered completely in control plate. The per cent inhibition (PI) of the fungus over control was calculated using the following formula:

$$PI = \frac{A - B}{A} \times 100$$

where, A is colony growth of the fungus in control plate and B is the colony growth of the fungus in treated plate.

Antagonistic effect of *Trichoderma* spp. against collar rot and stem rot pathogens

Potentiality of ten native isolates of *Trichoderma* spp. were tested against *Sclerotium rolfsii* and *Rhizoctonia bataticola* by dual culture technique. Mycelial disc of five mm diameter of *Trichoderma* (seven days-old culture) isolates and the soil borne pathogens were placed on the opposite of the plate at equal distance from the periphery of the plate containing PDA media. Inoculated plates were incubated at 27 ºC. Fungicide (hexaconazole 5% SC @ 2

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ml/l) was used as chemical standard check. All the above treatments were replicated thrice in completely randomized design along with control plate of pathogen. Per cent inhibition was calculated as follows (Table 3).

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

where, C = Mycelial growth in control and T = Mycelial growth in treatment

RESULTS AND DISCUSSION

In vitro evaluation of different fungicides against stem rot and dry root rot pathogens of groundnut

All the fungicides were very effective against *Rhizoctonia bataticola* at all concentrations and the per cent inhibition of mycelail growth ranged from 97.7 to 100. There was no significant difference observed between different concentrations used for each fungicide except SAFF (Table 1). Among different fungicides tested against colony growth of *Sclerotium rolfsii*, maximum inhibition (100.0%) was recorded by fungicides *viz.,* hexaconazole 5% SC, tebuconazole 250 EC, vitavax power 75% WP at all concentrations tested and there was no significant differences observed between different concentrations of fungicides. Next best fungicide was tebuconazole 2 DS (Raxil) where inhibition ranged from 96.1 to 99.2 per cent at all concentrations tested. In mancozeb fungicide treatment,the per cent inhibition ranged from 47.3 to 90.7 at different concentrations used. However, carbendazim was not much effective against *Sclerotium rolfsii* as per cent inhibition ranged from 0.0 to 48.8 only at different concentrations tested. Fungicide having combination product of mancozeb and carbendazim (SAFF) was also effective against *Sclerotium* as per cent inhibition ranged from 30.2 to 97.7 at different concentrations (Table 2).

Anitha Chowdary (1997) evaluated *in vitro* sensitivity of bell pepper isolate of *S. rolfsii* to captan, thiram @ 25, 50, 100, 250, 500 and 1000 ppm and propiconazole @ 10, 20, 25, 50, 100, 250 and 500 ppm and observed that propiconazole at a concentration of 250 ppm was effective in complete inhibition of *S. rolfsii*. Radhaiah (2012) also reported that mancozeb @ 0.2% completely suppressed the pathogen. Madhuri and Narayana Reddy (2013) reported the in vitro evaluation of nine fungicides by poison food technique and showed that tebuconazole and combination of carbendazim + mancozeb were effective in inhibiting the mycelial growth (94.1%) followed by difenconazole (93.3%). Das *et al*. (2014) reported that the effect of hexaconazole (systemic) has been highly effective in suppressing radial expansion as well as per cent inhibition of the *S.rolfsii* at all the concentrations used followed by Carboxin 37.5% + Thiram 37.5% (combo Fungicide) and tebuconazole.

Isolation and evaluation of *Trichoderma* spp. against collar rot and stem rot pathogens

Ten *Trichoderma* sps. were isolated from rhizophere soil of groundnut from different mandals of Chittoor district. All the ten isolates differed significantly in reduction of radial growth of *Rhizoctonia* when compared to growth of pathogen in control . Radial growth of *Rhizoctonia bataticola* ranged from 0.0 to 70.0 mm in all the treatments and was par with chemical check hexaconazole. Among different treatments, significant reduction of radial growth of *Rhizoctonia* was recorded in isolates CT7, CT8 and CT10. Next best treatment was *Trichoderma* spp. CT6 (Table 3). Per cent inhibition of *Rhizoctonia bataticola* ranged from 72.1 to 100.0 among all the isolates tested including chemical check (hexaconazole). Significantly higher inhibition was obtained using *Trichoderma* isolates CT7 and CT8 which were at par with the chemical standard check hexaconazole. Next best reduction was obtained by isolates of *Trichoderma* spp. CT5 and CT6 (Table 3).

Radial growth of *Sclerotium rolfsii* ranged from 0.0 to 70.0 mm in all the treatments including chemical control. Significantly less radial growth was obtained using isolates of *Trichoderma* spp. CT7 and CT8 which was at par with chemical check hexaconazole CT10 (Table 3). Among different bio-control agents, significantly higher per cent inhibition of *Sclerotium rolfsii* was recorded using isolates of *Trichoderma* isolates CT7 and CT8 which was at par with the chemical standard check hexaconazole (Table 3). The effectiveness local isolates of *Trichoderma* in inhibiting the growth of *S.rolfsii* up to 80 per cent under *invitro* conditions has been reported by Ganesan *et al.* (2007) and Bosah *et al.* (2010).

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Table 1. Mean per cent inhibition of colony growth of *Rhizoctonia bataticola* by using seven fungicides through poisoned food technique

Concentration of fungicides used (ppm)	Mancozeb 75% WP	Tebuconazole 2 DS (Raxil)	Carbendazim 50% WP	SAFF 75% WP	Hexaconazole 5% SC	Tebuconazole 250 EC (Folicur)	Vitavax power 75% WP
500	100.0 (85.9)	97.7 (81.1)	100.0 (85.9)	97.7 (81.1)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
1000	100.0 (85.9)	100 (85.9)	100.0 (85.9)	98.4 (82.7)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
2000	100.0 (85.9)	100 (85.9)	100.0 (85.9)	99.2 (84.3)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
3000	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)	99.2 (84.3)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
4000	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)	99.2 (84.3)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
SEm±	-	-	-	2.0	-	-	-
CD at 5%	NS	NS	NS	4.6	NS	NS	NS
CV (%)	-	-	-	3.0	-	-	-

Figures in parenthesis are angular transformed values; NS=Non significant

Table 2. Mean per cent inhibition of colony growth of *Sclerotium rolfsii* (Stem rot) using seven fungicides through poisoned food techniques

Concentration of fungicides used (ppm)	Mancozeb 75% WP	Tebuconazole 2 DS (Raxil)	Carbendazim 50% WP	SAFF 75% WP	Hexaconazole 5% SC	Tebuconazole 250 EC (Folicur)	Vitavax power 75% WP
500	47.3 (43.4)	96.1 (78.7)	0.0 (4.0)	30.2 (33.3)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
1000	74.4 (59.6)	96.9 (79.9)	17.8 (24.9)	65.1 (53.8)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
2000	83.7 (66.3)	97.7 (81.1)	38.3 (38.5)	82.9 (65.6)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
3000	92.2 (72.1)	98.4 (82.7)	44.2 (41.7)	86.8 (68.7)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
4000	90.7 (72.1)	99.2 (84.3)	48.8 (44.3)	96.1 (78.9)	100.0 (85.9)	100.0 (85.9)	100.0 (85.9)
SEm±	1.8	1.8	0.9	1.9	-	-	-
CD at 5%	4.0	4.0	2.0	4.1	NS	NS	NS
CV (%)	3.5	2.7	3.7	3.8	-	-	-

Figures in parenthesis are angular transformed values; NS=Non significant

Table 3. *In vitro* evaluation of *Trichoderma* isolates against fungal pathogens stem rot and dry root rot of groundnut

Treatments	*Trichoderma* spp.	Radial growth (mm)		Per cent inhibition over control	
		Rhizoctonia bataticola	***Sclerotium rolfsii***	***Rhizoctonia bataticola***	***Sclerotium rolfsii***
T1	CT1	8.7 (16.9)	11.0 (18.9)	87.6 (69.6)	84.3 (67.1)
T2	CT2	9.7 (18.0)	18.7 (25.6)	86.2 (68.3)	73.3 (58.9)
T3	CT3	7.3 (15.7)	17.0 (24.3)	89.5 (71.1)	75.7 (60.5)
T4	CT4	10.0 (18.4)	15.0 (22.8)	85.7 (67.8)	78.6 (62.4)
T5	CT5	7.0 (15.3)	16.0 (23.3)	90.0 (71.6)	77.1 (61.7)
T6	CT6	6.7 (14.9)	17.0 (24.3)	90.5 (72.0)	75.3 (60.5)
T7	CT7	0.0 (4.0)	0.0 (4.0)	100.0 (85.9)	100.0 (85.9)
T8	CT8	0.0 (4.0)	0.0 (4.0)	100.0 (85.9)	100.0 (85.9)
T9	CT9	12.0 (20.2)	14.7 (22.5)	72.1 (65.5)	65.9 (62.7)
T10	CT10 (Hexaconazole)	0.0 (4.0)	0.0 (4.0)	100.0 (85.9)	100.0 (85.9)
T11	Control	70.0 (56.8)	70.0 (56.8)	--	--
	SEm ±	1.2	1.9	1.6	2.4
	CD at 5%	2.4	3.9	3.3	5.1
	CV (%)	6.5	8.0	2.6	4.3

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EVALUATION OF FOXTAIL MILLET (*Setaria italica* L.) BASED INTERCROPPING SYSTEMS UNDER LATE SOWN CONDITIONS

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ABSTRACT

A field experiment was conducted during late *kharif,* 2016 at S.V. Agricultural College Farm, Tirupati, ANGRAU with three different times of sowing of foxtail millet (first fortnight of August, second fortnight of August and first fortnight of September) in combination with four intercropping systems (foxtail millet + pigeonpea (5 : 1), foxtail millet + castor (5 : 1), foxtail millet + black gram (3 : 3) and foxtail millet + cowpea (3 : 3)). The results of the experiment revealed that among the three times of sowing, first fortnight of August sowings recorded higher stature of growth, yield attributes and yield of foxtail millet and intercrops. The above parameters were at their lower value with first fortnight of September sowings. Intercropping system of foxtail millet + pigeonpea (5 : 1) resulted in higher growth and yield of foxtail millet while, they were found to be at their lower values with foxtail millet + cowpea (3 : 3) intercropping system. Sowing of foxtail millet + pigeonpea (5 : 1) intercropping system during first fortnight of August proved to be viable risk minimizing strategy under late sown conditions.

KEYWORDS: Foxtail millet, times of sowing, intercropping system, growth, yield.

Millets have been called ¨Nutri grains¨ since they are rich in micro nutrients like minerals and B complex vitamins. Small millets have gained their attention owing to their inherent capacity of early maturity, higher yields due to C_4 plant type, capacity to yield even in poor soil under low rainfall and poor management conditions; hence they are popularly known as ¨climate resilient¨ crops in Indian agriculture. Small millets provide much needed food and fodder security of the nation. Among minor millets, foxtail millet and barnyard millet have low glycemic index. Consumption of these grains has demonstrated positive health benefits among the diabetics and they are known as ¨wonder grains¨.

Foxtail millet can be planted when it is too late to plant most other crops. It keeps growing with 300 – 400 mm annual rainfall also in semi arid areas. As it is a climate resilient crop because of the potential abiotic stress tolerance, it can ensure ecological security also. To stabilize crop production and to provide insurance against aberrant weather situations in rainfed agriculture, intercropping of millets with pulses such as pigeonpea could be a viable risk minimizing agronomic means of sustainable venture. Especially the information on promising intercropping systems under delayed monsoon conditions has been lacking which is required for contingency planning. Hence, promising foxtail millet based intercropping systems were tested for their response to different times of sowing to evaluate their yield potentiality.

MATERIAL AND METHODS

A field experiment was carried out during late *kharif*, 2016 at S.V. Agricultural College Farm, Tirupati. The experimental soil was sandy loam in texture, slightly acidic in reaction (pH 6.1), medium in organic carbon (0.52 per cent) and low in available nitrogen (185 kg ha^{-1}), high in available phosphorus (28 kg ha^{-1}) and medium in potassium (204 kg ha^{-1}). The experiment was laid out in split-plot design with twelve treatment combinations and replicated thrice. The treatments comprised of three times of sowing (first fortnight of August, second fortnight of August and first fortnight of September) and four intercropping systems (foxtail millet + pigeonpea (5 : 1), foxtail millet + castor (5 : 1), foxtail millet + black gram (3 : 3) and foxtail millet + cowpea (3 : 3)). Foxtail millet as well as intercrops were sown in lines, 30 cm apart by adopting all the standard package of practices. Recommended dose of fertilizer (50 kg N 30 kg P_2O_5 and 20 kg K_2O) was applied to foxtail millet only in all the treatments. The scheduled nitrogen was applied in two equal splits *viz.,* first half at the time of sowing as basal and remaining half as top dressing at 30 DAS.

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Table 1. Growth parameters of foxtail millet at harvest as influenced by times of sowing and intercropping systems

Treatments	Plant height (cm)	Leaf area index	Number of tillers m^{-2}	Dry matter production (kg ha^{-1})
Times of sowing				
T_1 : I Fortnight of August	102.8	1.43	3.8	2975
T_2 : II Fortnight of August	93.5	1.15	3.0	2787
T_3 : I Fortnight of September	88.7	1.11	2.5	2723
SEm±	2.19	0.033	0.10	46.9
CD (P=0.05)	8.6	0.13	0.4	183
Intercropping systems				
C_1 : Foxtail millet + pigeonpea (5 : 1)	106.3	1.52	3.4	3119
C_2 : Foxtail millet + castor (5 : 1)	103.0	1.38	3.4	3090
C_3 : Foxtail millet + black gram (3 : 3)	88.7	1.11	2.9	2560
C_4 : Foxtail millet + cowpea (3 : 3)	81.9	0.90	2.7	2544
SEm±	3.67	0.079	0.16	44.3
CD (P=0.05)	10.9	0.23	0.4	132
Interaction				
C at T				
SEm±	4.39	0.066	0.20	93.7
CD (P=0.05)	NS	NS	NS	NS
T at C				
SEm±	5.93	0.123	0.28	81.3
CD (P=0.05)	NS	NS	NS	NS

RESULTS AND DISCUSSION

Effect of times of sowing on growth and yield of foxtail millet

Among the three different times of sowing evaluated, taller plants, maximum leaf area and higher total number of tillers $hill^{-1}$ and dry matter production of foxtail millet were noticed with first fortnight of August sowing and was significantly superior to rest of the two times of sowing, which were comparable with each other. Lower values of these growth parameters were registered when the sowing was done during first fortnight of September (Table 1).

The yield attributing characters of foxtail millet *viz.,* number of productive tillers $hill^{-1}$, number of panicles m^{-2}, panicle length, panicle weight and grain weight $panicle^{-1}$ were found to be significantly higher with the first fortnight of August sowing and was having significant disparity with that of other two times of sowing, which were on par with each other. Lower values of these yield attributes were produced when sowing was done during first fortnight of September (Table 2). Thousand grain weight of foxtail millet was not significantly influenced by different times of sowing.

First fortnight of August sowings produced significantly higher grain and straw yields of foxtail millet which was significantly superior to that of other two times of sowing, which were on par with each other. While grain and straw yields of foxtail millet were at their lower value with first fortnight of September sowing (Table 2). Superiority of early sown foxtail millet crop in plant height, number of tillers, leaf area has resulted in higher

Table 2. Yield attributes of foxtail millet as influenced by times of sowing and intercropping system

Treatments	Panicle length (cm)	Panicle weight (g)	Grain weight panicle^{-1} (g)	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Times of sowing						
T_1 : I Fortnight of August	12.6	3.60	2.04	2.60	823	1565
T_2 : II Fortnight of August	10.9	3.35	1.71	2.58	767	1227
T_3 : I Fortnight of September	10.5	3.25	1.56	2.54	753	1063
SEm±	0.39	0.062	0.04	0.03	12.3	69.3
CD (P=0.05)	1.5	0.24	0.2	NS	48	271
Intercropping systems						
C_1 : Foxtail millet + pigeonpea (5 : 1)	12.4	3.79	2.16	2.70	974	1553
C_2 : Foxtail millet + castor (5 :1)	11.8	3.51	1.93	2.60	966	1539
C_3 : Foxtail millet + black gram (3 : 3)	10.8	3.13	1.62	2.50	599	1036
C_4 : Foxtail millet + cowpea (3 : 3)	10.2	3.10	1.52	2.49	587	1012
SEm±	0.32	0.121	0.12	0.04	23.8	66.7
CD (P=0.05)	0.9	0.36	0.3	0.1	71	198
Interaction						
C at T						
SEm±	0.78	0.12	0.09	0.06	24.7	138.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS
T at C						
SEm±	0.63	0.19	0.17	0.07	37.8	121.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS

dry matter accumulation which has contributed to higher values of yield attributes and was reflected in higher grain and straw yields. The results were in conformity with the findings of Rao *et al.* (1991); Jadhav *et al.* (1995) and Ramachandrappa *et al.* (2016).

Effect of intercropping on growth and yield of foxtail millet

Higher expression of all the growth parameters and yield attributes of foxtail millet were observed with the intercropping system of foxtail millet + pigeonpea (5 : 1), which was in parity with foxtail millet + castor (5 : 1) intercropping system. While all these parameters were at their lower value with the intercropping system of foxtail millet + cowpea (3 : 3) (Table 1 & 2).

Significantly higher grain and straw yields of foxtail millet were observed with the intercropping system of foxtail millet + pigeonpea (5 : 1), which was comparable with foxtail millet + castor (5 : 1) intercropping system. While lower grain and straw yields were registered with foxtail millet + cowpea (3 : 3) intercropping system (Table 2).

Higher grain and straw yields with the intercropping of foxtail millet + pigeonpea (5 : 1) might be due to significantly higher plant population of foxtail millet, productive tillers per hill, panicles per m^2, panicle length and grain weight per panicle at 5 : 1 row ratio than that at 3 : 3 row ratio coupled with the better complementary relationship with the intercrop in the system. As pigeonpea and castor are long duration crops, their initial growth was slow providing foxtail millet enough time to grow, establish and achieve higher grain and straw yields. But the growth of cowpea and black gram crops was vigorous in the early stages leading to smothering effect which resulted in lower grain and straw yields of foxtail millet. Similar results were obtained by Shashidhara *et. al.* (2000); Basavarajappa *et al.* (2002) and Padhi *et al.* (2010).

Higher productivity of foxtail millet could be obtained with intercropping system of foxtail millet + pigeonpea (5 : 1) sown during first fortnight of August during *kharif* season, indicating its suitability for cultivation under late sown conditions.

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